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ACQUISITION RISK MANAGEMENT GUIDANCE

JUNE 14, 1994

DEPARTMENT OF TRANSPORTATION

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DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
EXECUTIVE DIRECTOR FOR ACQUISITION AND SAFETY OVERSIGHT
OFFICE OF ACQUISITION POLICY AND OVERSIGHT
ACQ-10

ACQUISITION RISK MANAGEMENT GUIDE

JUNE 14, 1994

PLEASE READ THIS NOTE BEFORE CONTINUING.

THIS IS GUIDE IS DESIGNED TO PROVIDE ASSISTANCE TO A DEVELOPER OF AN ACQUISITION RISK MANAGEMENT PLAN IN SEVERAL WAYS. PLEASE <u>DO NOT</u> LET THE SIZE OF THIS DOCUMENT SCARE YOU AWAY FROM USING IT. (1) IT PROVIDES A TUTORIAL FOR A NOVICE OR SOMEONE WITH RUSTY SKILLS. (2) IT PROVIDES NUMEROUS CHECKLISTS TO MAKE A DEVELOPER'S JOB EASIER AND QUICKER. -AND (3) IT PROVIDES NUMEROUS APPENDICES OF INFORMATION, TO BE EMPLOYED AS NECESSARY, DEPENDING ON THE SCOPE AND COMPLEXITY OF THE ACQUISITION RISK MANAGEMENT PLAN UNDER DEVELOPMENT. THE TABLE OF CONTENTS IS REALLY AN OUTLINE AS WELL, AND THE PREFACE AND FOREWORD PROVIDES A BETTER INSIGHT INTO THE SCOPE, APPROACH AND DESIGN OF THIS GUIDE, AND SHOULD BE READ BEFORE STARTING TO USE THIS GUIDE. REGARDLESS, THE CHAPTERS AND APPENDICES OF THIS GUIDE SHOULD BE EMPLOYED SELECTIVELY, AND THE THOSE NOT NEEDED SHOULD BE VIEWED AS HANDY REFERENCES. IT IS NOT AS AWESOME AS IT FIRST APPEARS. WE BELIEVE THAT USERS OF IT WILL FIND IT VERY USEFUL ONCE THEY BECOME FAMILIAR WITH IT, AND EMPLOY IT IN THE DEVELOPMENT OF AN ACQUISITION RISK MANAGEMENT PLAN.

This Guide was produced under the authorization and supervision of the Executive Director for Acquisition and Safety Oversight, AXQ-1 (Martin A. Phillips, Actg), and the Office of Acquisition Policy and Oversight, ACQ-1 (David Morrissey). Coordination, research, assembly, original authorship and initial editing of the first edition was provided by Anthony F. Osborne, while on detail to ACQ-1 from the Flight Service Stations Program office, ANW-500. That detail was fully supported by ANW-500 (Rudolph Watkins), ANW-1 (Alvin L. Thomas), and-1 (John E. Turner), not only to produce this product, but to ensure that the final product would be both an educational/tutorial publication on Acquisition Risk Management, as well as, a practical and useful guide, that could be used to produce Acquisition Risk Management Plans at any level. Additional significant critical review and comments, for the first edition, was provided by Roger Martino, Martin Johnson, David Woodson and George Sweger, all of ACQ-10. Suggestions, comments and inquiries regarding this publication should be directed to ACQ-10.

PREFACE

PREFACE

The Office of Management and Budget (OMB) Circular A-109 states that, "For a number of years, there has been deep concern over the effectiveness of the management of major systems acquisitions."[1] It further explains that, the coverage of the circular applies to (a) Management of the acquisition of major systems, and (b) All programs for the acquisition of major systems even though the system is one-of-a-kind. The General Accounting Office (GAO) Report GAO/RCED-93-55[2] cites FAA for not as being attentive to risk management as it otherwise should be, when processing Major Systems Acquisitions. Those documents and reports stimulated introspective activities to improve the management of risk in processing major systems acquisitions at the FAA. In order to improve performance in the risk management area, senior management decided to have an acquisition risk management guide produced that would provide usable definitions, guidance and templates. This guide is a result of those decisions and subsequent efforts. It centers on three key areas:

- o Program Management is risk management; therefore, the program manager's job is to manage risk.

- o Management of risk not only requires the management of technical risk, but also includes management of programmatic risk, supportability risk, cost risk, and schedule risk. All are important in program management.

- o Risk management is accomplished by: (1) Identifying risks to the program as early as possible; (2) Determining the cause(s) for each risk, and its significance to the program; and (3) Developing and implementing effective abatement measures that either eliminate the risk, provide sound control measures to minimize its effects on the program, or provide adequate resources to manage assumed risks.[3]

There are no complete "textbook" answers to risk management. Each situation is different and each circumstance requires a slightly different approach. This guide, therefore, cannot be a panacea. It does, however, present several concepts and methodologies, and provides definitions which will assist program management offices in developing risk management programs and plans.

This Risk Management Guide was developed by the Federal Aviation Administration's Office of Acquisition Policy and Oversight, ACQ-1. It contains not only original and FAA-specific perspectives regarding risk management, but it is also a compendium of other government publications. It draws heavily from the Defense Systems Management College's Risk Management Concepts and Guidance guidebook[4], the FAA ORDER 1810.1F[5], the Air Force Materiel Command (AFMC) Acquisition Risk Management Guide[6], and the Department of Defense Instruction 5000.2[7]. Significant credit must be given and grateful appreciation conveyed to the authors of those publications. Other references are cited throughout the guide, and information excerpted from all of them has been screened for applicability to FAA processes.

Recent developments and emphasis on nondevelopmental item (NDI) and commercial off the shelf (COTS) acquisitions and utilization, has caused the FAA to begin reviewing how such items can be more fully employed in National Airspace Systems. A full chapter has been reserved to develop that topic, but will not be complete by the time this publication goes to press as the 'interim/first' edition. It is expected that topic within this guide will become a critical part of the guide as it becomes more visible. That chapter will be developed before the first revision is released.

This guide was printed using circle folio printing guidance. Both sides of all pages within a chapter or appendix are numbered and accounted for, however blank pages are usually silently numbered. Actual content will usually start with page 3 of each chapter. All material will appear on paper stock that is recyclable.

ENDNOTES / REFERENCES

1. Circular A-109; Major Systems Acquisitions; Executive Office of the President; Office of Management and Budget; April 5, 1976; P1. (This circular remains in effect.)

2. Report to the Chairman, Subcommittee on Transportation and Related Agencies, Committee on Appropriations, House of Representatives; (Subject) Air Traffic Control; Justifications for Capital Investments Need Strengthening; United States General Accounting Office; January 1993; GAO/RCED-93-55 Air Traffic Control; P1, 8-9.

3. ACQUISITION RISK MANAGEMENT GUIDE; Air Force Materiel Command (AFMC); Preliminary version, August 20, 1992.

4. Risk Management Concepts and Guidance; Defense Systems Management College (DSMC); 1987; U.S. GPO; Washington, D.C.

5. ORDER 1810.1F; ACQUISITION POLICY; Department of Transportation; Federal Aviation Administration; March 19, 1993; Washington, D.C.

6. Op cit; ACQUISITION RISK MANAGEMENT GUIDE, AFMC.

7. Instruction 5000.2; Defense Acquisition Management Policies and Procedures; Department of Defense; February 23, 1991.

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FOREWORD

FOREWORD

This Risk Management Guide is designed to provide program management offices with a reference for dealing with program risks related to systems acquisitions. There is no single "best" technique for managing risk. This guide provides an introduction to the concepts of risk and an overview of the techniques for managing risk. This approach allows the readers to select the most appropriate risk strategy for their circumstances. This guide alerts readers to the many problems and issues faced in acquisition risk management and deals with issues raised by the GAO Report[1].

This guide has also been designed as a reference book for practical application, and is intended to aid all levels of program management and designated "risk" analysts.

SCOPE

This guide is limited to "acquisition" risk management as it relates to the FAA programs and projects. It does not cover "security," "insurance," "safety," or "accident" risks, which are generally considered to be outside of the FAA acquisition management realm. Rather, focus, from a program office viewpoint, is placed on acquisition risk management. Program management offices are charged with the responsibility of making decisions which inherently have an element of uncertainty. There is no absolute distinction, therefore, between program management and risk management. Risk management is an integral part of the program management function. Risk management should be thought of as a program management methodology, rather than an independent and isolated function distinct from other program management functions.

Risk Management is a method of managing that concentrates on identifying and controlling the areas or events that have a potential of causing unwanted change. It is informed management.

APPROACH

Acquisition risk is approached in this handbook from a holistic viewpoint. It is addressed as a single entity, consisting of different facets (technical, programmatic, supportability, cost, and schedule). While technical issues are a primary source of risk, they must be balanced with the management of other aspects of the program: the other facets.

NOTES ON USE OF THIS GUIDE

While using this guidebook, keep in mind that risk is a complex concept subject to individual perception. Some people are risk takers and some people are risk averse. Hence, it is difficult to develop a universal set of rules for dealing with risk. Guidance, structure, and sample handling techniques are contained in this guide, which follow sound management practices. While the principles, practices and theories presented herein hold true in nearly all situations, under certain circumstances the rules by which risk is evaluated may change drastically. For example, in times of extreme threat, people do extraordinary things. They will take risks that under ordinary circumstances would be deemed unacceptable. High risk programs, therefore, are not always bad, and the acquisition of high risk programs should not necessarily be avoided: rather they should be rigorously monitored and controlled.

DESIGN

This guide is designed to serve several purposes, as described in the Preface, and as outlined in the Table of Contents of this guide. They include providing a tutorial on acquisition risk management, a chapter which is a guide to developing an Acquisition Risk Management Plan (ARMP), and appendices which delve into very detailed analyses processes. The primary reason for developing this guide was to assist 'program people' in producing ARMPs. Most of the information needed to construct an Acquisition Risk Management Plan (ARMP) is contained in the main body of this document. For programs of expansive scope and complexity, appendices are provided, which provide more detail on several subjects. Although this guide has become somewhat voluminous in some respects, it is not difficult to understand or apply, and the checklist approach it employs in many areas will save a lot of development time in the long-run, provide a consistent way of doing business, jog the ARMP developers' thinking process, and help the developer to avoid omissions. It is suggested that the guide be used as follows:

- o If a user is new to the Acquisition Risk Management discipline and associated specialty areas, he should digest Chapters 1, 2, 3, 5 and 6 before attempting to put together an ARMP.
- o If the developer is experienced, and the program under scrutiny is not too complex, then he may go directly to Chapter 4 and begin 'filling in the blanks.'
- o On the other hand, if a complex, expansive or highly visible program is under scrutiny, then the material and detail in the several appendices should be considered as well.

A final product ARMP thus created (using the processes enumerated in this ARMP guide) will more likely satisfy all concerned.

MONITORING ORGANIZATION

Like the products that will result from the application of this guide, this guide is a living document as well. Suggestions, reports of errata, and suggested amendments and modifications should be directed to the FAA, Office of Acquisition Policy and Oversight, attention Anthony Osborne.

Figure F.1 Quick Look-up Reference Chart.

PROCESS STEPS

GUIDE CHAPTERS/SECTIONS	DETERMINING THE NEED	UNDERSTANDING RISK	PLANNING FOR RISK MANAGEMENT	ORGANIZING FOR RISK MANAGEMENT	REQUIRING CONTRACTOR RISK MANAGEMENT	RISK IDENTIFICATION	RISK QUANTIFICATION	ANALYZING PROGRAM RISKS	COMMUNICATING RISK	HANDLING RISK	MONITORING CONTRACTOR RISK MANAGEMENT	RESEARCHING RISK MANAGEMENT	TOOLS	POLICY	PROBABILITY THEORY
INTRODUCTION 1-1	✓														
RISK CONCEPTS 3-1		✓										✓			
RISK DEFINITION 3-1		✓										✓			
RISK FACETS & INTERRELATIONSHIPS 3-4		✓										✓			
RISK MANAGEMENT PERSPECTIVES 3-9		✓										✓			
RISK MANAGEMENT STRUCTURE 4-1			✓			✓	✓	✓		✓		✓			
RISK MANAGEMENT PLANNING 4-1			✓	✓			✓								
RISK ASSESSMENT 4-5						✓	✓								
RISK ANALYSIS 4-9								✓							
RISK HANDLING 4-12										✓					
EXECUTING THE RISK MANAGEMENT PROCESS 5-1				✓		✓	✓	✓	✓	✓		✓	✓		
ASSESSMENT TECHNIQUES 5-3 TO 5-20				✓		✓	✓						✓		
ANALYSIS TECHNIQUES 5-20 TO 5-53						✓	✓	✓					✓		
HANDLING TECHNIQUES 5-54										✓			✓		
RISK MANAGEMENT IMPLEMENTATION 6-1			✓	✓	✓	✓						✓			
ORGANIZATION 6-2			✓	✓											
RESOURCES 6-8			✓			✓									
TECHNIQUE SELECTION 6-7 TO 6-17			✓			✓		✓							
COMMUNICATING RISK DATA 6-19			✓				✓	✓	✓						
CONTRACTOR RISK MANAGEMENT 7-1					✓					✓	✓				
GOVERNMENT RESPONSIBILITIES 7-1					✓					✓	✓				
CONTRACTOR RESPONSIBILITIES 7-3					✓					✓	✓				
THE FUTURE OF RISK MANAGEMENT 8-1												✓			
APPENDICES A THRU G													✓	✓	✓
BASIC PROBABILITY E-1		✓					✓								✓
POLICY C-1	✓		✓											✓	

ENDNOTES / REFERENCES

1. Op cit; Report to the Chairman; P-4.

CHAPTER 1

INTRODUCTION

1. INTRODUCTION

1.1 PURPOSE

This FAA Acquisition Risk Management Guide (FARM-Guide) is structured for use by individuals and organizations with widely varying knowledge and experience in the risk management arena. It contains sections, from ones that are tutorial in nature, for users with little or no experience, to sections that contain templates and checklists, for users who already have a background and experience in this subject. This guide also allows the author of an Acquisition Risk Management Plan (ARMP) to tailor a plan in relation to the size and complexity of a program. A sample plan is included in the appendices, that indicates what a basic RMP should look like for a rather straight-forward program. That program consists of about 60 local area networks, made up of (COTS) microprocessor driven computers, tied together with some COTS operating system software, and will employ application specific software that will be written, using specifications derived from an already existing system. A review of the Table of Contents will reveal that it is also an outline. If you are new to this area, start at the beginning of the guide. If you are experienced, skip over to Chapter 4, and go to work. In any case, employ Chapters 5, 6 and 7, and draw on the material in the appendices as needed.

This guide follows policies and procedures, which establish the basis for managing risk, consistent with the guidelines contained in OMB Circular A-109[1]; FAA ORDER 1810.1F[2]; the DSMC "Risk Management Concepts and Guidance" guidebook[3]; and the DoD Instruction 5000.2, "Defense Acquisition Management Policies and Procedures,"[4].

This section authorizes the employment of a template approach in development of risk management plans for acquisition programs for the FAA.

1.2 POLICIES

1.2.1 The 1810.1F, Section 1-10i(3), Risk Management, requires that "a formal, tailored program of risk evaluation and reduction shall be established for each Level I, IIIA, and IVA program. Risk and risk reduction measures shall be assessed at each key decision point before granting approval to proceed to the next acquisition phase." The major risk facets to be addressed will be (as a minimum) technical, programmatic, supportability, cost and schedule, and others as they are applicable to a specific subject program. Risk areas to be assessed shall include technology, design and engineering, manufacturing and production processes, producibility, operational, support, cost, and schedule, The acquisition plan shall contain provisions for eliminating or reducing risks to acceptable levels. An initial risk management plan shall be developed during Phase 1 and maintained throughout the acquisition process.

1.2.2 An acquisition risk management plan (RMP) shall be produced for each acquisition program to identify and control performance, cost, and schedule risks associated with the technical, programmatic, supportability, cost and schedule facets, using the areas of risk identified in 3.2, following. The RMP must include provisions for eliminating these risks or reducing them to acceptable levels.

1.2.3 Where industry is involved in the areas of risk identified, industry participation in risk management is essential to ensure a clear understanding of program objectives, produce schedule realism, and identify appropriate incentives for contractual agreements.

1.3. PROCEDURES

1.3.1 Essential Program Characteristics. The ARMP will consist of planning, identification, assessment, analysis, and reduction techniques to support sound program management decisions. It will:

- o Include a structured and documented risk assessment and analysis process, with user participation, to identify risks early in the program and to provide proactive, look ahead risk assessment and review;

- o Include clearly defined criteria for elements leading to the risk assessment events. The satisfaction of these criteria must be documented to support the rigor necessary in the risk assessment process;

  For design reviews, which are necessary to assess the risk of design, the steps that comprise the criteria leading to the Preliminary Design Review (PDR) and the Critical Design Review (CDR) are depicted by the following list of Design Events:

  Design Policy
  Design Requirements
  System/Subsystem Architecture
  Preliminary Schematics/Layout
  Software Preliminary Design
  Preliminary Physical Design
  Software Detailed Design
  * Preliminary Design Review
  Design Rules and Guidelines
  Software Code Inspections
  Physical Design versus Requirements
  Analysis (Functional, Thermal, Electrical, Power and Reliability)
  Product Drawings & Associated Lists
  Testing (Software Modules, Integration, and System)
  Installation & Field Manuals

* Critical Design Review

o Include assessment of the contractor's managerial, development, and manufacturing capabilities and processes;

o Identify and track risk drivers, define risk abatement plans, and provide for continuous risk assessment throughout each acquisition phase to determine how risks have changed; and

o Provide clearly defined evaluation criteria for assigning risk ratings of high, moderate, or low to elements of risk associated with each major subsystem and the overall system.

1.3.2 Milestone Decision Point Reviews. As an integral part of this effort, risks, risk reduction measures, rationale and assumptions made in assigning risk ratings, and alternative acquisition strategies will be explicitly assessed at each milestone decision point. The acquisition strategy will be reviewed at each milestone to ensure it adequately accounts for the degree of risk associated with the maturity of the technology involved in the system and with concurrency in the program.

1.3.3 ARMP Factors to Address. The ARMP shall address the factors of Systems Engineering, including Engineering Management; Logistics Support Analysis; the Manufacturing Management Program; Software Development; Human Engineering Requirements for Systems, Equipment, and Facilities; and Technical Reviews and Audits for Systems, Equipments, and Computer Programs. The policies and procedures that follow establish the basis for integrating the technical efforts of the entire design team to meet program cost, schedule, and performance objectives with an optimal design solution that encompasses the system and its associated manufacturing, test, and support processes.

1.3.4 System Engineering Application. Systems engineering shall be applied throughout the system life cycle as a comprehensive, iterative technical management process to:

o Translate an operational need into a configured system meeting that need through a systematic, concurrent approach to integrated design of the system and its related manufacturing, test, and support processes;

o Integrate the technical inputs of the entire development community and all technical disciplines..., into a coordinated effort that meets established program cost, schedule, and performance objectives;

o Ensure the compatibility of all functional and physical interfaces (internal and external) and ensure that system definition and design reflect the requirements for all system elements: hardware, software, facilities, people, and data; and

o Characterize technical risks, develop risk abatement approaches, and reduce technical risk through early test and demonstration of system elements.

- o Technical risks will be identified and assessed throughout the acquisition cycle.

- o The acquisition strategy must include provisions for eliminating these risks or reducing them to acceptable levels.

- o Effects of technical risk on program cost and schedule, risk reduction measures, rationale and assumptions made in assigning risk ratings, and alternative acquisition strategies will be explicitly assessed at each milestone decision point.

1.3.5 GAO Criteria. The RMP shall address five criteria[5] (GAO cites) that are essential to assessment of technical risk.

1 Prospective assessment: Possible future technical problems are considered, not just current problems.

2 Planned procedures: Assessment is planned and systematic, not incidental.

3 Attention to technical risk: There is explicit attention to technical risk, not just to schedule or cost with consideration of technical risk left implicit.

4 Documentation: At a minimum, technical risk assessment procedures and results are written down in some form.

5 Reassessment in each acquisition phase: New or updated assessments are made in order to detect changes in risk during a system's development.

As the reader progresses through this guide, the importance of adhering to these criteria will become more evident. Without an understanding of the complexity of dealing with risk, these criteria appear to be merely reasonable. With an understanding of the complexity of risk, their importance is seen as critical. It is the intent of this guide to bring the reader up to a knowledge level where these criteria are viewed as mandatory for successful risk management.

ENDNOTES / REFERENCES

1. Op cit; Circular A-109.

2. Op cit; ORDER 1810.1F.

3. Op cit; Risk Management Concepts and Guidance.

4. Op cit; Instruction 5000.2.

5. Technical Risk Assessment: The Status of Current DOD Efforts; U.S. General Accounting Office; April, 1986.

CHAPTER 2

BACKGROUND

2. BACKGROUND

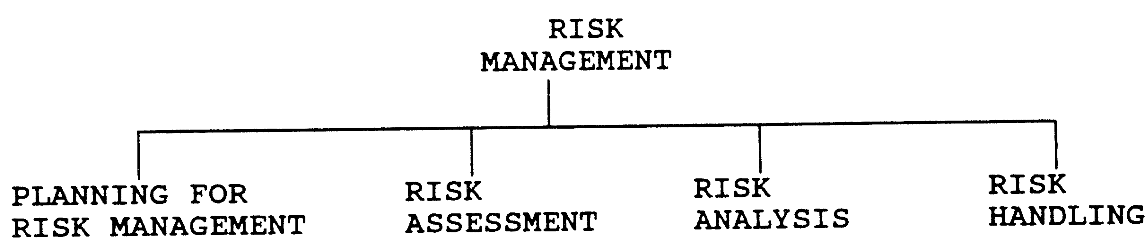
2.1 HISTORY

In 1986, the United States General Accounting Office released a report titled; Technical Risk Assessment - The Status of Current DoD Efforts, which examined the methodology used for assessing technical risks within 25 program offices. Since that time emphasis has never ceased regarding risk assessment, either in the DoD or civilian agencies. This guide has been developed to assist program managers, and other concerned parties, in addressing risk both for new undertakings as well as established programs.

2.2 THE ISSUE OF FORMALITY

In order for the risk management process to work, it must become formal, systematic, and applied in a disciplined manner within the organization: in other words, institutionalized. That is not to say that all programs should require extensive formal risk management. It does mean that to obtain the maximum benefit from risk management, it must become a systematic process. There have been, historically, several problems which prohibited risk management from becoming a clearly understood process. The intent of this guide is to address these problems and thereby lay the groundwork for institutionalizing risk management. Risk management refers to the sum total of four specific elements. Assessment, Analysis, and Handling refer to the actual execution of the process, while Planning represents most of preparation activity.

Figure 2.1 Risk Management Structure



2.3 THE RISK MANAGEMENT NEED

Most decisions, including the most simple, involve risk. Take for example, the decision of whether to drive or fly on a business trip?: The cost and time differentials are easily obtained, but the safety factor and the probability of arriving on time for a meeting can become very complicated.

With this example in mind, a "success criteria" is necessary early in the effort in order to set down the most important elements in the risk assessment. If cost alone is the only success criterion, then the risk determination is simple; determine the cost to fly and compare this to the expense of driving. The next success criterion might be safety. One method of transportation will be safer than the other. Statistics concerning accidents per 1000 miles traveled are available to evaluate this criterion. If a third criterion is added, such as on-time arrival for a meeting, then dependability of the transportation method must be entered into the calculation. Airline on-time statistics and the dependability of the automobile and the road conditions should be evaluated.

As the success criterion is expanded and made more complicated, the decision making becomes more complicated. It is obvious from the example that some risk (perhaps increased cost) is acceptable, while being late for the meeting may be an unacceptable risk. Certainly, not arriving safe and sound is completely unacceptable.

Today's National Airspace Systems are increasing in technical complexity, and this increasing complexity increases the risk. Program decisions are heavily biased toward cost and schedule goals. While cost and schedule are understood, the impact of cost/schedule decisions as they relate to technical performance risk are usually not clear. A formal methodology for evaluating the impacts of decision-making and foreseeable problems is necessary. In addition, this methodology should aid in identifying any practical and effective work-arounds in order to achieve the program goals.

Proper risk management requires a systematic approach to the identification of problems. The sizing and resolution of these problems can only help in the determination of choices, given certain causes and effects. In order to ensure that the approach is systematic, it would include the communication of risk as seen by each diverse technical function to the single decision maker in order to obtain the maximum program benefit in terms of performance, cost, and schedule.

While many program managers use intuitive reasoning (guessing) as the starting point in the decision-making process, it behooves the astute manager to go beyond the intuitive reasoning or experience factor in decisions involving significant risks. As a minimum, a manager should attempt to obtain the level of risk and the impact of the action on the progress of the program. If the risk is of such consequence as to cause the entire program to fail, then it may not be acceptable and some other plan must be formulated.

In today's National Airspace Systems environment, there are factors that must be carefully examined for risk in order to understand the necessity for risk management. The project manager must be aware of potential cost and schedule perturbations; frequently the survival of a project (and perhaps the manager) depends upon the control of these elements.

Given the above description of the National Airspace System environment and the qualifications for effective program management, it is advisable for all programs to perform some documented risk management activity, either qualitative or quantitative or both. All TSARC programs should have formal and intense risk management activities, while smaller and less critical programs may require less effort. The ultimate authority is the program manager. He/she must make the judgement based on performance, cost, and schedule challenges faced on the project.

In summary, (1) risk management is required by policy, (2) risk management should be formal and systematic, (3) risk is an integral part of decision-making, (4) greater pressure on the FAA requires more effective risk management, and (5) almost all programs should have some level of documented risk management activity.

ENDNOTES / REFERENCES

CHAPTER 3

RISK CONCEPTS

3. RISK CONCEPTS

3.1 EXPANDED DEFINITION OF RISK

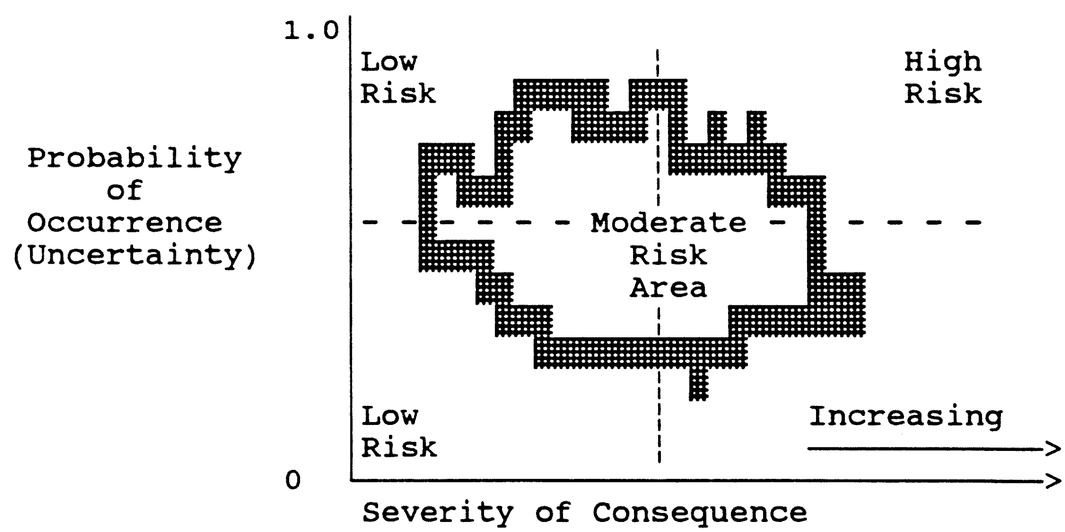
3.1.1. **Probability** is defined as (1) the chance that a given event will occur, and (2) a logical relation between statements such that evidence confirming one confirms the other to some degree.[1]

3.1.2. **Risk** is defined as the probability of an undesirable event occurring and the significance of the consequence of the occurrence. This is different than uncertainty, as described below. It is also different from the traditional (statistical) view of risk which defines risk as a situation in which an outcome is subject to an uncontrollable random event stemming from a 'known' probability distribution.

3.1.3. **Uncertainty** (or possibility) considers only the likelihood of occurrence of an event. The event may not be undesirable. Uncertainty is normally thought of in traditional terms (statistically) as an outcome subject to an uncontrollable random event stemming from an 'unknown' probability distribution.

3.1.4. Potential impacts. Risk and uncertainty are often used interchangeably, but **they are not the same.** Therefore, to truly understand whether an item is "risky," one must have an understanding of the potential impacts resulting from the occurrence or nonoccurrence of the event. Figure 3.1-1 illustrates this concept.

Figure 3.1-1 Concept of Risk



3.1.5. There are three separate inputs required to determine the level of risk...

- o First, Probability of occurrence of the event.
- o Second, Severity of consequence if the event should occur.
- o Third, Subjective judgement concerning the combination of the first two.

3.2 RISK FACETS

After obtaining an understanding of the nature of risk, the next step is to lay the ground-work for managing it. Risk must be segmented into manageable pieces, The first "cut" is to break it into classifications relating to the source of the risk. Figure 3.2-1 illustrates this approach.

3.2.1 Introduction. Risks to a program manager are all rooted in the determination to deliver a specified product or level of performance at a specified cost. The program manager risks failure in three ways and combinations thereof: (1) The product may not be up to the performance level specified, (2) the actual costs may be too high, or (3) the delivery may be too late.

3.2.2 Classifying Risk into the facets. Understanding and classifying a risk into one or more of the five facets (Technical, Programmatic, Supportability, Cost or Schedule) requires an examination of the source of the risk. It is not always easy to determine into which category a particular risk belongs. However, understanding the source of the risk and the impact areas as well as providing a structure to examine risk are critical elements if the risk is to be managed effectively.

3.2.3 Technical Risk. Technical risk can be defined as the risk associated with (1) evolving a new design to provide a greater level of performance than previously demonstrated, or (2) the same or lesser level of performance subject to some new constraints. The nature and causes of technical risks are as varied as NAS systems designs. Many, if not most, technical risks are the result of the demand for ever greater performance from new systems and equipment. What is technically risky when first attempted may be routine a few years later. Risky areas on a system with high performance requirements may be routine on other systems with lower performance requirements. The ever present requirement to minimize or maximize physical properties of systems and equipment further adds to the risks associated with higher performance requirements.

Many of the "ilities," such as Producibility, Supportability, Maintainability, and Reliability, must be addressed in system acquisition. Each can be viewed as additional design requirements placed on designers attempting to evolve an efficient design capable of the desired performance level. Each of these design requirements can be a source of risk.

It is not easy to describe all possible technical risks, because, when examined at the lowest level of detail, there are so many of them. There are usually many items to be designed and integrated with other items, and many design objectives for each site. Appendix A contains an abbreviated list of technical risk areas.

3.2.4 Programmatic Risk. Programmatic risk can be defined as those risks which include obtaining and using applicable resources and activities which may be outside of the program's control, but can affect the program's direction. Generally, programmatic risks are not directly related to improving the state-of-the-art. Programmatic risks are grouped into categories based on the nature and source of factors that have the potential to disrupt the program implementation plan: (1) Disruptions caused by decisions made at higher levels of authority directly related to the program; (2) Disruptions caused by events or actions affecting the program, but not directed specifically at it; (3) Disruptions caused primarily by the inability to foresee production related problems; (4) Disruptions caused by imperfect capabilities; and (5) Disruptions caused primarily by the inability to foresee problems other than those included in the first four categories. These risks tend to be a function of the business environment.

Figure 3.2-1   Sample Risks by Facet

TYPICAL TECHNICAL RISK SOURCES	TYPICAL PROGRAMMATIC RISK SOURCES	TYPICAL SUPPORTABILITY RISK SOURCES	TYPICAL COST RISK SOURCES	TYPICAL SCHEDULE RISK SOURCES
Physical Properties	Material Availability	Reliability & Maintainability	Sensitivity to Technical Risk	Sensitivity to Technical Risk
Material Properties	Personnel Availability*	Training*	Sensitivity to Programmatic Risk	Sensitivity to Programmatic Risk
Radiation Properties	Personnel Skills*	O & S Equipment*	Sensitivity to Supportability Risk	Sensitivity to Supportability Risk
Testing/Modelling	Safety	Manpower Considerations*	Sensitivity to Schedule Risk	Sensitivity to Cost Risk
Integration/Interface	Security	Facility Considerations*	Overhead/G & A Rates	Degree of Concurrency
Software Design	Environmental Impact	Interoperability Considerations	Estimating Error	Number of Critical Path Items
Safety	Communication Problems	Transportability*		Estimating Error
Requirement Changes	Labor Strikes	System Safety		Labor Strikes
Fault Detection	Requirement Changes	Technical Data*		Contractor Stability
Operating Environment	Political Advocacy	Logistics		The Contracting Process
Proven/Unproven Technology	Contractor Stability	Configuration Management		Manufacturing
System Complexity	Funding Profile			Production
Unique/Special Resources	Regulatory Changes			
Hardware Design	Engineering			
Integration Design	The Contracting Process			
Engineering	Training*			
Training*	Manufacturing			
	Production			

* Logistical Element

3.2.5 Supportability Risk. Supportability risk can be defined as the risk associated with fielding and maintaining systems which are currently being developed and are being deployed. Note that supportability risk is comprised of both technical and programmatic aspects. Certainly, any design effort (which may contain technical challenges) should consider what the supportability issues are likely to be when the system is fielded. Another example is training, which is generally a programmatic risk, but quickly becomes a supportability risk when maintenance and operations support become driving factors. There are ten Integrated Logistics Support Elements that present potential sources of risk. These involve both technical and programmatic issues. They are (1) Maintenance Planning; (2) Manpower and Personnel; (3) Support Equipment; (4) Technical Data; (5) Training; (6) Training Support; (7) Computer Resources Support; (8) Facilities; (9) Packaging, Handling, Storage and Transportation; and (10) Design Interface.

It is important to understand that any given risk area may belong to more than one facet as illustrated above (e.g., a particular piece of support equipment may pose a technical challenge ***and*** have significant supportability implications.)

3.2.6 Cost Risk. Cost risk and Schedule risk are so very closely related that most Government publications refer to them collectively as Cost/Schedule risk. The next five paragraphs will discuss the topic in that manner, however additional paragraphs starting at 3.2.6.6 and 3.2.7 will break them out separately in order to provide more detail and individual expansion.

3.2.6.1 History. There is a long history of FAA program cost/schedule growth with considerable Congressional criticism thereof. In an era of limited FAA budgets, cost/schedule growth in one program dictates reductions in one or more others. Therefore, the risk of cost/schedule growth is a major concern. This problem is further complicated by the fact that performance and design technical problems are sometimes solved by increasing the planned scope and thereby program cost/schedule (and schedule).

3.2.6.2 Growth. Cost/schedule growth is the difference between the estimated program cost/schedule and the actual cost/schedule. Therefore, there are two major cost/schedule risk areas bearing on cost/schedule growth: (1) The risk that the estimate set an unreasonably low cost/schedule objective; and (2) The risk that the program will not be carried out in an efficient and prudent manner so as to meet reasonable cost/schedule objectives.

3.2.6.3 Outcomes as a function of management skill. The outcome of the second of these two risk areas is not primarily a cost/schedule analysis related risk, that is, anything cost/schedule analysts or financial analysts can control. The final costs/schedules are primarily a function of the skill of the Program Manager to accommodate unanticipated problems related to technical, supportability, and programmatic risks. The solution or the lack of a good solution for such problems often increases costs and schedules.

3.2.6.4 Low baseline cost/schedule estimates. The preparation of an unrealistically low baseline cost/schedule estimate or program target cost/schedule estimate fall into four categories (prior to the pricing decision). They are: (1) Inadequate system description; (2) Inadequate historical cost/schedule database; (3) Lack of sound methods relating historical costs/schedules to new program costs/schedules; and (4) Incomplete cost/schedule estimate.

3.2.6.5 Summary. Note that from this context, there are few true cost or schedule risks. There are occasions where this statement does not hold true. For example, test windows can drive entire programs to a degree, as can funds available for a specific item. Generally, true cost and schedule risks are few and far between, when the source of the risk is closely examined. More often than not, cost and schedule uncertainty are a reflection of technical, programmatic and supportability risk.

3.2.6.6 Cost Estimating. The cost estimating process is described in detail in other documents (see Appendix B) and will not be described in detail here. However, a review of the basic methods is in order. There are four methods used in cost estimating: *published factors, engineering build-up, analogy, and parametric cost estimating.*

o *Published factors* are simple estimating relationships developed to cover aspects of a program. Stating that it costs $350 and six hours to prepare an engineering drawing is an example of a factor.

o *Engineering Build-up* is the most detailed method. It is a bottoms-up approach, based on defining each element of work and estimating the time and cost for each work element. The work measurement system used by manufacturing to determine how much effort it takes to build a system is an example of the engineering build-up approach.

o *Analogy* is based on determining how comparable the proposed system is to an existing system whose development cost are known. The estimate of the new system is then derived as being the cost of the existing system, multiplied by an adjustment factor (or k factor) for the differences.

o *Parametric Cost Estimating Relationships (CERs)* are based on the assumption that the cost of a system is driven by one or more system-level factors. Using historical data on several systems, an equation for the relationship between the cost and the system-level factors is determined. To estimate the cost of the new system, its system-level factors are estimated, and fed into the equation. This then becomes the estimate of developing the system. Software development estimating models such as COCOMO[2] are based on this approach.

Cost Estimate Development. Once the estimator has the appropriate estimating parameters and risk factors, the program cost estimate can be developed. The cost analyst, working with the technical staff, will identify the appropriate models and methods for developing the estimate. The expected program cost is then derived for the development program.

Risks are factored into the cost estimate based on their handling approaches. Risks which are avoided or re-allocated do not, of course, affect cost because they are no longer part of the program. For those risks which are specific information gathering or risk controls actions are planned, the cost for those actions will be factored into the program's expected cost estimates. This occurs in two ways:

- o First, if the cost impact is significant, and an estimating method is available, the analyst will separately estimate the cost of those actions. For example, if the program plans to build and test an instrument test vehicle, the cost required for that effort can be estimated separately. The technical staff can assist these estimates by identifying comparable efforts accomplished in the past where cost data might be available.

- o Second, the impact of risk may have been accounted for in the comparability factors developed by the technical staff and the analyst. This can be used to account for minor information gathering and risk control actions, for which separate estimates are not worth the effort to create them.

Effects of Assumed Risks. The effects of assumed risks are handled differently. The basic concept is to bound the expected cost estimate with a high and low estimate. There are at least three techniques that can be used:

- o First, establish the bounds directly based on expert judgment.

- o Second, conduct a sensitivity analysis on the estimating method used. This is especially useful when some form of estimating relationship or analogy method is used. For example, suppose system weight is used in an estimating relationship with cost. A cost bound could be established by using the high and low estimates for the system weight (using the ranges discussed in preceding sections).

o Third, Estimate costs based on an estimate of the work that must be done. That is, we may estimate that developing a new electronics box may need one retest for each qualification test. A set of bounds could be established by varying the amount of the retest that could be needed. This would then affect the cost of the item.

An important point to remember is that cost is normally proportional to the schedule. Therefore, when bounding estimates are made, the schedule should be bound first. Cost variation can then include the impact of the schedule variation.

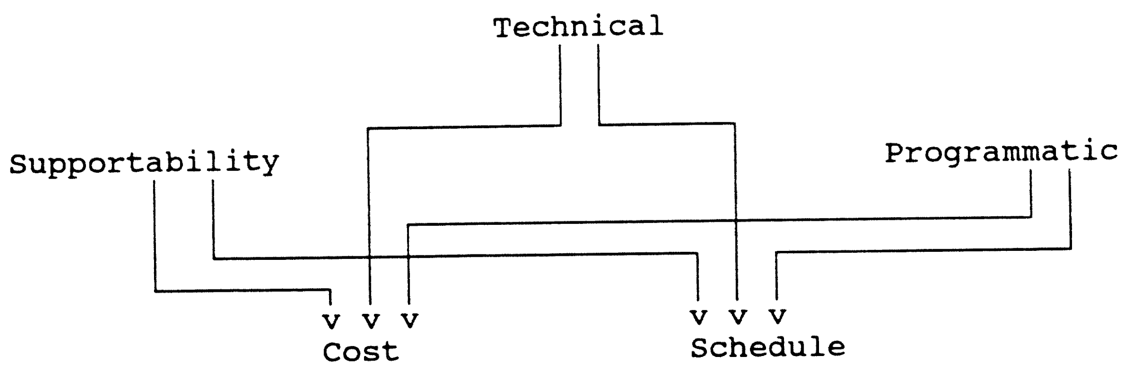
Bounding estimates can be done at both the system level and at lower levels in the WBS. If done at a lower level, the analyst has several techniques available to aggregate the bounding estimates at the system level. Several references are listed in Appendix B.

3.2.7 Schedule Risk. Schedule risk and Cost risk are so very closely related that most Government publications refer to them collectively as Cost/Schedule risk. Paragraphs 3.2.6 through 3.2.6.5, above, discusses the topic in that manner, however additional paragraphs starting at 3.2.7.1, following, will break Schedule risk out separately in order to provide more detail and individual expansion. Appendix J discusses the schedule estimating process.

3.2.8 Facet Organization. It was mentioned previously that there are "risk drivers" and "risk indicators." The risk drivers are usually the technical, programmatic, and supportability facets, which leave the cost and schedule facets as the indicators. This is often, but not always the case. Generally when an item is contracted for, there is a specified performance level to be met. This includes design criteria, supportability factors, performance criteria and a host of other specifics. It is then asked, "what will it actually take to build this item in terms of resources (time and money)?" It is paramount that the item satisfy the need. The tendency then is to focus on the performance requirements: not cost or schedule. Unfortunately cost and schedule tend to be the yardstick by which decisions are made, and the tradeoffs between cost, schedule and performance are not well understood. This is one of the advantages of performing risk management. It attempts to draw reality into the relationship between the risk facets.

There are occasions where a project is undertaken with the understanding that the product will be the best possible within the dollar and time constraints dictated. In these instances the cost and schedule facets become the drivers and the other facets may become the indicators. Few projects have such clear cut goals. More often than not, the program management office must strive to achieve a balance between the facets to reach seemingly conflicting goals in performance, cost and schedule. For simplicity, this guide will treat technical risk, programmatic risk and supportability risk as the predominate factors driving cost risk and schedule risk. This is illustrated in Figure 3.2-2.

Figure 3.2-2. Relationship Between The Five Risk Facets



By now it is easy to see that the risk facets are not independent of one another. While a design risk is of a technical nature it may have cost, schedule, supportability, and programmatic impacts. Or, a tight test window presenting a schedule risk, may have serious technical impacts. The facets may also change with time. What started as a technical risk in the design of a product may surface years later as a supportability risk factor that has serious cost and schedule impacts. A useful approach is to examine all facets *whenever* a risk is identified in one facet.

This discussion was not intended to imply that cost and schedule manage themselves: that is not true. The intent was to emphasize the importance of managing the *source* of the risk in any program. Frequently, this is some factor rooted in technical, programmatic or supportability characteristics.

3.3 OTHER RELEVANT CONSIDERATIONS

There are two points worthy of mention when discussing risk concepts from a program office viewpoint. Both deal with our acquisition management structure (to a degree) and are discussed in the following two sections.

3.3.1 Two Perspectives of Risk Management. Program/project risk management must be viewed from two perspectives defined as follows: (1) Short term - addressing the current program phase and immediate future; and (2) Long term - addressing anything beyond the short term. Like many other aspects of risk management, the distinction between the two perspectives is somewhat unclear. Further explanation will help to clarify and justify the separation. The short term perspective normally refers to managing risk related to satisfying the immediate needs of the project, i.e., "this is the performance level I need to achieve today," and, "how are my contractors managing to achieve this?" The long term perspective deals with "what can I do to ensure that downstream the program will be successful?" This might include, among other things, introducing supportability engineering and producibility engineering into the design process early in the program. The two perspectives are closely related. In achieving the desired performance level (short term goal) materials that are difficult to work with and/or require new manufacturing techniques as yet unproven may be utilized to solve the problem (introducing a long term risk.) As with any good management decisions, the short term and long term implications must be well understood. Only if these implications are known can they be acted on (risk handling) early enough to significantly reduce the chance of undesirable results. Another look at the two perspectives to aid in understanding the differences is illustrated in 3.3-1. In this figure an overall design has been selected for a given project, which has certain elements of risk. This was a decision that obviously had long term implications. The task now at hand for the program manager is to complete the design selected within the resources made available. This particular program manager has selected some technical, cost, and schedule parameters to manage "risk" on an operational day to day basis (short term risk management). Again, this does not preclude his decisions in managing short term risk from having significant long term impacts.

3.3.2 Realities of the Government Program Office Function. Under ideal program management conditions, the same management team would stay with a program from the definition phase through production. However, ideal conditions rarely exist and a given program will likely see several management teams. The transition in program management personnel often creates voids in the risk management process. These voids are in the information / knowledge gained about the program from previous activity. Precious time must be spent becoming familiar with the program, often at the sacrifice of long term planning and risk management. The introduction if a formal system for recording, analyzing, and acting on a program risk facilitates the transition process, and when done properly, forces long term risk management. The approach to formal risk management is contained in Chapters 4, 5 and 6. While it is desirable to make decisions based on long term implications, it is not always feasible. The program management office is often forced to act on risk from a short term rather that a long term perspective. One reason has already been mentioned: the change in personnel. Another reason is program advocacy. Sudden shifts in priorities can wreck havoc on long term plans: this is a risk area in and of itself. The result is short term actions to adjust to new priorities. Often these kinds of decisions are made before a thorough evaluation of the long term impacts can be conducted. Lastly, in some instances, long term impacts are not always visible at a time the decision must be made.

There are day to day operational risks that must be addressed to complete any given phase of a program. The solutions developed to handle these risks must always be examined from a long term viewpoint and must provide the program manager a strong argument to defend his/her position. As has been pointed out in many studies, actions taken early in a program's development have a major effect on the overall performance and cost over the life of the program as illustrated in Figure 3.3-2.[3]

Figure 3.3-1. Short/Long Term Risk Perspective.

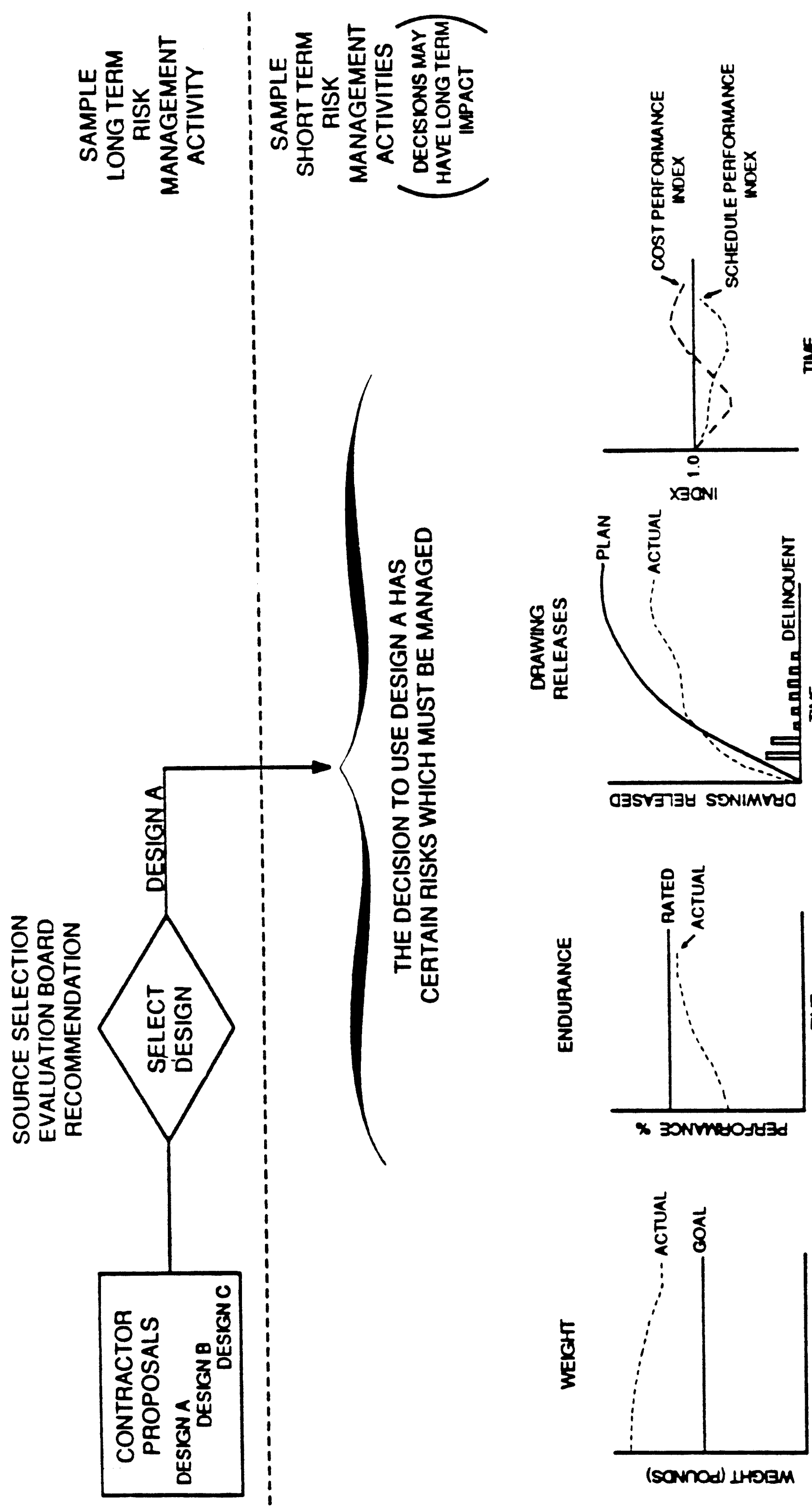
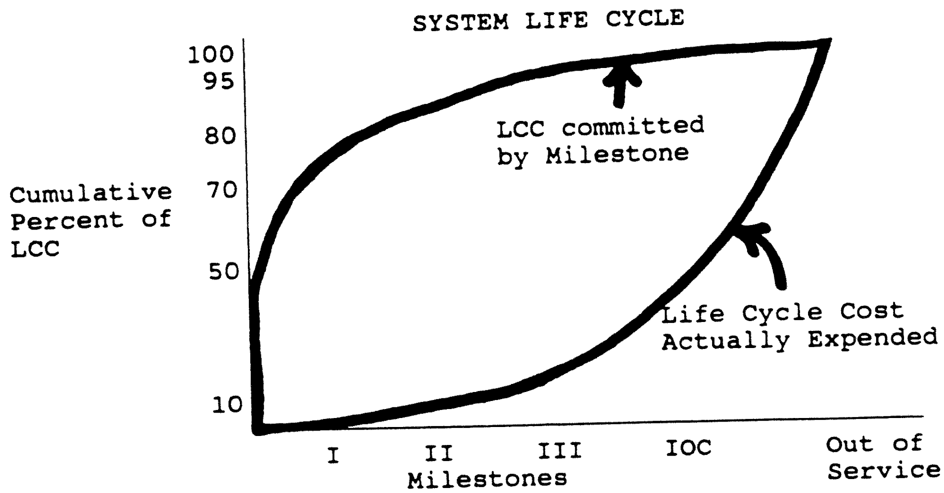
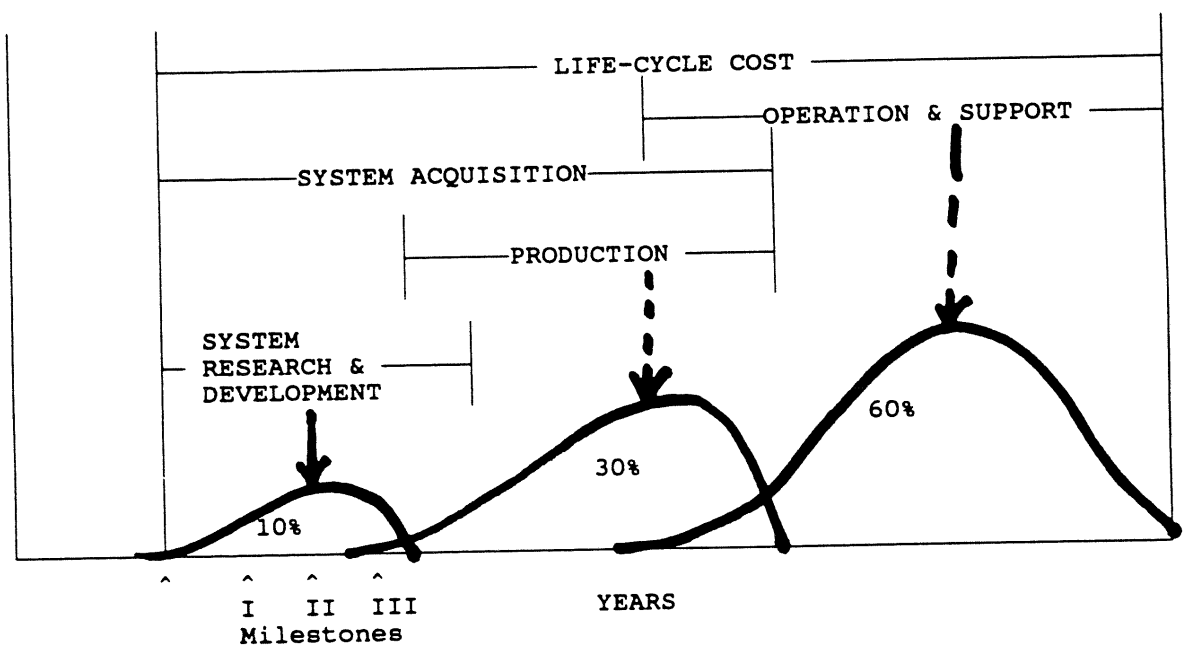


Figure 3.3-2. Life Cycle Costs Illustrated





ENDNOTES / REFERENCES

1. Webster's Ninth New Collegiate Dictionary; Merriam Webster; Springfield, Mass; 1990.

2. COCOMO. Constructive Cost Model; Software Engineering Economics; Boehm, Barry; 1981. A software cost and schedule estimating methodology, derived from a study of 63 software projects. It is non-proprietary.

3. Integrated Logistics Support; Defense Systems Management College; Fort Belvoir, VA; October 1985.

CHAPTER 4

THE RISK MANAGEMENT STRUCTURE

4. THE RISK MANAGEMENT STRUCTURE

4.1 INTRODUCTION

This chapter presents the recommended structure for executing risk management. Recognition must be given to the fact that in the past there have been several different structures and definitions used for basically the same concept. This has been a source of continuing confusion in the field of risk management. Figure 4.1-1 illustrates the most common of the previous terminology / structures used in the risk field. It is important to note that all of these previous structures/approaches do not clearly distinguish between the terms risk assessment / risk analysis / risk management. Previous efforts have not established standard terminology. This chapter will clarify and define each of these terms so that communications regarding "risk" can be more effective. Risk management consists of four separate but related activities as depicted in Figure 4.1-2. *Risk Management* is the *umbrella* title for the processes used to manage risk. This chapter focuses on defining and explaining the elements of risk management. As with any process, there are two basic stages: planning, and then execution, which includes monitoring and control.[1]

4.2 RISK PLANNING

4.2.1 Need/Purpose

Risk is present in some form and degree in most human activity. It is present in the systems acquisition business. Risk is characterized by the fact that: (1) It is usually at least partially unknown; (2) It changes with time; and (3) It is manageable, in the sense that human action may be applied to change its form and degree.

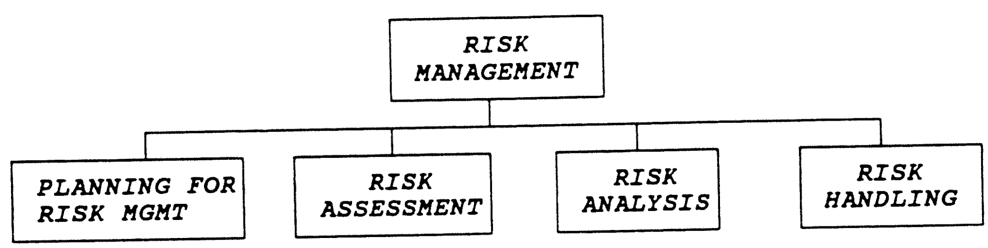
Planning for the management of risk makes ultimate sense in order to: (1) Eliminate risk wherever possible; (2) Isolate and minimize risk; (3) Develop alternative courses of action; and (4) Establish time and money reserves to cover risks that cannot be avoided.

The **purpose of risk management planning** is simply to force organized purposeful thought to the subject of eliminating, minimizing, or containing the effects of undesirable occurrences.

Figure 4.1-1 Older Definition of Risk Management Structure and Activity

```
EVALUATION
        Risk Assessment        <-┐
                                 │
ALTERNATIVE CREATION             │
                                 │
ALTERNATIVE EVALUATION           ├──> RISK
        Risk Assessment        <-┘    ASSESSMENT <-┐
                                                   ├──> RISK
ALTERNATIVE SELECTION                              │    ANALYSIS
        Risk Reduction         <-┐    RISK         │
                                 │    REDUCTION    │
IMPLEMENTATION                   ├──>              │
        Risk Reduction           │    RISK         │
        Risk Management        <-┘    MANAGEMENT <-┘
```

Figure 4.1-2. Updated Risk Management Structure and Activity.



4.2.2 Timing

Risk is a word that exists only in the future tense. There are no past risks - only actual occurrences.

Risk management planning is sensibly done and redone as an integral part of normal program planning and management. Some of the more obvious points for revisiting the Risk Management Plan (RMP) include: (1) In preparation for major decision points; (2) In preparation for and immediately following technical reviews and audits; (3) Concurrent with the review and update of other program plans and specifications; and (4) In preparation of CIP submittals.

4.2.3 Risk Management Plan

Most major programs are guided by a series of plans such as a PMP and TEMP that provide the rationale and intended processes through which the program will be executed. A Risk Management Plan is a sensible part of this suite of guiding documents. Such a plan would publish the results or latest status of the risk management planning process.

The System Description (PART I, following) and Program Summary (PART II, following) should be the same in all of the program's plans. It should provide the basis of reference for the reader to understand the operational need, the mission, and the major functions of the system. It should include key operational and technical characteristics of the system.

The Program Summary (PART II) should include a description of the organizational relationships and responsibilities of the participating organizations. It would also include an integrated program schedule.

The Approach to Risk Management (PART III) should describe (declare) the intended approach (specific to the program) for executing the processes of: (1) Risk Assessment; (2) Risk Analysis; and (3) Risk Handling. Also appropriate to be included under this topic area would be definitions, measurement techniques, and risk rating methods for Technical, Programmatic, Supportability, Cost and Schedule risks. A description of the structure to be used to identify and assess program / project risks, and an overview of the methods and techniques for risk analysis would be valuable.

Figure 4.2-1. THE RISK MANAGEMENT PLAN OUTLINE AND TEMPLATE

1. PART 1 - DESCRIPTION

1.1 MISSION

1.2 SYSTEM
1.2.1 SYSTEM DESCRIPTION
1.2.2 KEY FUNCTIONS

1.3 REQUIRED OPERATIONAL CHARACTERISTICS

1.4 REQUIRED TECHNICAL CHARACTERISTICS

2. PART 2 - PROGRAM SUMMARY

2.1 SUMMARY REQUIREMENTS

2.2 MANAGEMENT

2.3 INTEGRATED SCHEDULE

3. PART 3 - APPROACH TO RISK MANAGEMENT

3.1 DEFINITIONS
3.1.1 TECHNICAL RISK DEFINITION
3.1.2 PROGRAMMATIC RISK DEFINITION
3.1.3 SUPPORTABILITY RISK DEFINITION
3.1.4 COST RISK DEFINITION
3.1.5 SCHEDULE RISK DEFINITION

3.2 STRUCTURE

3.3 METHODS OVERVIEW
3.3.1 TECHNIQUES APPLIED
3.3.2 IMPLEMENTATION

4. PART 4 - APPLICATION

4.1 OVERALL PROGRAM RISK

4.1.1 RISK ASSESSMENT FOR
4.1.1.1 RISK IDENTIFICATION
4.1.1.2 RISK QUANTIFICATION
4.1.1.3 IDENTIFICATION SUMMARY
4.1.2 RISK ANALYSIS
4.1.3 RISK MANAGEMENT (HANDLING TECHNIQUES)
4.1.3.1 RISK MITIGATION AND REDUCTION MILESTONES
4.1.3.2 RISK QUANTIFICATION
4.1.3.3 RISK BUDGETING
4.1.3.4 CONTINGENCY PLANNING

Figure 4.2-1. THE RISK MANAGEMENT PLAN OUTLINE AND TEMPLATE (continued)

4.2 HARDWARE RISK

4.2.1 RISK ASSESSMENT
4.2.1.1 RISK IDENTIFICATION
4.2.1.2 RISK QUANTIFICATION
4.2.1.3 IDENTIFICATION SUMMARY
4.2.2 RISK ANALYSIS
4.2.3 RISK MANAGEMENT (HANDLING TECHNIQUES)
4.2.3.1 RISK REDUCTION MILESTONES
4.2.3.2 RISK QUANTIFICATION
4.2.3.3 RISK BUDGETING
4.2.3.4 CONTINGENCY PLANNING

4.3 SOFTWARE RISK

4.3.1 RISK ASSESSMENT
4.3.1.1 RISK IDENTIFICATION
4.3.1.2 RISK QUANTIFICATION
4.3.1.3 IDENTIFICATION SUMMARY
4.3.2 RISK ANALYSIS
4.3.3 RISK MANAGEMENT (HANDLING TECHNIQUES)
4.3.3.1 RISK REDUCTION MILESTONES
4.3.3.2 RISK QUANTIFICATION
4.3.3.3 RISK BUDGETING
4.3.3.4 CONTINGENCY PLANNING

4.4 INTEGRATION RISK

4.4.1 RISK ASSESSMENT (NAS and/or OTHER SYSTEMS
4.4.1.1 RISK IDENTIFICATION
4.4.1.2 RISK QUANTIFICATION
4.4.1.3 IDENTIFICATION SUMMARY
4.4.2 RISK ANALYSIS
4.4.3 RISK MANAGEMENT (HANDLING TECHNIQUES)
4.4.3.1 RISK REDUCTION MILESTONES
4.4.3.2 RISK QUANTIFICATION
4.4.3.3 RISK BUDGETING
4.4.3.4 CONTINGENCY PLANNING
4.4.3.5 MANAGEMENT

5. PART 5 - SUMMARY

5.1 RISK PROCESS SUMMARY

5.2 TECHNICAL RISK SUMMARY

5.3 PROGRAMMATIC RISK

THE RISK MANAGEMENT PLAN OUTLINE AND TEMPLATE (Fig. 4.2-1)
(continued)

5.4 SUPPORTABILITY RISK SUMMARY

5.5 SCHEDULE RISK SUMMARY

5.6 COST RISK SUMMARY

5.7 CONCLUSIONS

APPENDICES

A BIBLIOGRAPHY

B ACRONYMS / GLOSSARY

C FILE OF CHRONOLOGICAL SUPPORTING DOCUMENTATION

ENDNOTES / REFERENCES

SUBJECT INDEX

APPROVAL RECORD

ATTACHMENTS

Application Issues (PART IV) will include procedures and processes for: (1) Identifying risks; (2) Quantifying risk; (3) Use of tools to analyze risk; and (4) Applying specific actions to manage risk. This is where a risk management planner performs and records his detailed work.

Other relevant plans that help govern major programs are i.e., Program Management Plans (PMPs), System Engineering Management Plans (SEMPs), Acquisition Plans (Aps), Test and Evaluation Master Plans (TEMPs), Manufacturing Plans (Mps), and Integrated Logistics Support Plans (ILSPs). These plans provide insights into items of risk. Typically they are not written from a risk viewpoint, but when one reads them with an eye to raising risk questions, they provide valuable information. These plans should be reviewed before, during, and after preparation of the Risk Management Plan. These plans may suggest items of risk. The Risk Management Plan may suggest items that need to be addressed in the other plans. While the Risk Management Plan deals with analyzing and managing risk, risk should be identified and highlighted in any or all plans where it is appropriate.

4.3 RISK ASSESSMENT

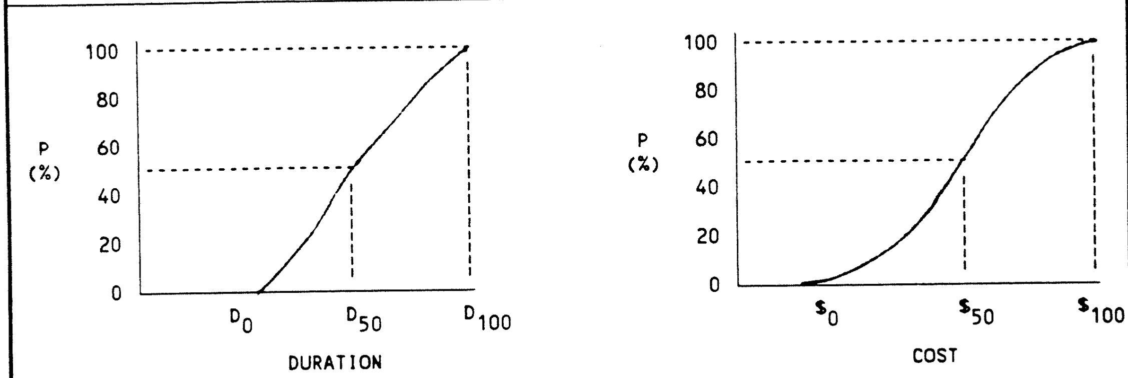
4.3.1 Identification

Risk identification is the first step in the risk assessment process. Risks cannot be assessed or managed until they are identified and described in an understandable way. Risk identification is an organized thorough approach to seek out the real risks associated with the program. It is **not** a process of trying to invent highly improbable scenarios of unlikely events in an effort to cover every conceivable possibility of outrageous fortune.

Approaches - Expert interviews, analogy comparisons, and the evaluation of program plans are techniques that are especially strong in the risk identification segment. The objective of the risk identification segment is to obtain straight forward English language narrative statements describing the program risks. Mathematical techniques are not appropriate here. Chapter 5 describes in great detail the techniques for executing the risk management process: including risk identification.

Baselining Risk - Risk exists only in relation to the two states of uncertainty: total failure (usually 0% probability) and total success (usually 100% probability). The risk assessment process attempts to treat risk in a probabilistic manner and the process is significantly simplified if we are able to define total failure and total success. Defining one or both of the "baseline programs" is worth some effort in order to obtain a benchmark on the continuum (Figure 4.3-1). It is certainly desirable but difficult to describe the technical content of a 0% and a 100% probable schedule and cost values to achieve the technical content. After defining a baseline position, it becomes easier to quantify risk in terms of each impact area on a meaningful scale.

Figure 4.3-1. Risk Baselines



For baseline definition, we are seeking D0 and $0, or D100 and $100.

Checklist Concept - The purpose of any program is to achieve a specifiable set of goals. The basic risk identification question becomes, "What are the events or facts that may reasonably occur which will prevent the achievement of program goals?" Occurrences whose outcomes are irrelevant to program goals have no risk. The search should be directed toward the "show stoppers" that will have a major impact on the program. The key to risk identification is the systematic combing through the total program. Figure 4.3-2 offers a matrix that can serve as a tool to organize this process. The Top Level Risk Matrix is applied at the total program level as a starting point. The concept can be refined and carried to greater detail as needed.

Figure 4.3-2. Top Level Risk Matrix

		PROGRAM PHASE			
		CE/DV	FSD	PRODUCTION	DEPLOYMENT
TECHNICAL	GOALS				
	STRATEGY				
	RISKS				
PROGRAM	GOALS				
	STRATEGY				
	RISKS				
SUPPORT	GOALS				
	STRATEGY				
	RISKS				
COST	GOALS				
	STRATEGY				
	RISKS				
SCHEDULE	GOALS				
	STRATEGY				
	RISKS				

Defining Program Goals - One would expect this step to be an easy task. More than likely, it will be a thought provoking and controversial process. Requirements specified in the Program Management Plan (PMP) should all be included as goals. If direction is missing or not explicit enough to be included as a goal, this process identifies that fact (which in itself is an important risk reduction action). All goal blocks on the matrix should be covered. A goal block that cannot be filled out to the satisfaction of the program manager is an alert for direction and/or definition. The program manager should precipitate some action to fill the void.

Defining Program Strategies - Program strategies represent the plan(s) for achieving the goals. In the ideal case, the strategy blocks in the matrix should contain references to chapters or paragraphs in one or more of the program plans. If this is not the case, the plans are inadequate. This causes the greatest risk of all: that of not having a plan to reach a goal. The Top Level Risk Matrix can serve as a forcing function to insure the plans address all goals.

Identifying Risks - A simple first step in risk identification is to evaluate the appropriateness of the strategies against the goals. Counterproductive strategies cause risk. The very imperfect world of systems acquisition frequently forces the program manager to do things that are counterproductive or suboptimum. Highlighting these anomalies is a powerful contribution to risk identification.

4.3.2 Preliminary Quantification

After the risk identification process has produced a well documented description of the program risks and before risk analysis begins in earnest, some organization and stratification of the identified risks are beneficial. Preliminary quantification is intended to provide some prioritization of the risks for further evaluation. Heavy mathematical treatments is not desired here.

Rating Schemes and Definitions - The degree of risk existing in a given situation is a reflection of the personality of the risk taker. Twenty people can look at the same situation and assign twenty different risk values to it. A risk rating scheme built against an agreed set of definitions provides a framework for eliminating some of the ambiguity.

The rating system can (and probably should) be very simple: such as High, Medium or Low, using the notion that the degree of risk is a judgement reflecting the probability of occurrence and the severity of impact. The definition issue becomes one of identifying impacts and deciding on a scale(s) and then shopping the boundaries between the three regimes.

With a defined risk rating scheme in place (at least tentatively), the task of evaluating and quantifying each of the identified risks may be accomplished against this structure.

Interviewing Experts - The technique of interviewing experts is discussed in detail in Section 5.2. The objective is to gather information from the technical experts that will allow the analyst to rate the risk.

Using Analogies - Analogy comparison is discussed in detail in Section 5.3. It is an attempt to learn from other programs or situations. Analogy comparison is a technique used for many things, e.g., cost estimating. The caution in this case is to differentiate between "analogous programs" and "programs with analogous risks."

4.4 RISK ANALYSIS

4.4.1 Definition and Description

The transition from risk assessment activities to risk analysis activities is gradual. There is some amount of analysis that occurs during the assessment process. For example, if in the process of interviewing an expert, a risk area is identified, it is logical to pursue information on the magnitude of the risk, the consequences if the risk becomes a reality, and the possible ways of dealing with it. The latter two actions are generally considered a part of the analysis process, but occur during the risk identification activities of a formal risk management effort.

As time progresses in a grass roots risk management effort, the risk analysis function grows independent from the assessessment function. The process generally becomes more of a top level analysis with the impacts being evaluated against total project / program completion of subsystem completion. Risk Analysis involves an examination of the change in consequences caused by changes in the risk input variables. Sensitivity and "what-if" analysis are examples of the activities that should take place during risk analysis.

4.4.2 Risk Analysis Products

One of the most useful products of the analysis process is the watchlist. The watchlist serves as the worksheet that managers use for recording risk management progress.[2] An example of a watchlist is shown in Figure 4.4-1. Watchlists provide a convenient and necessary form to track and document activities and actions resulting from the risk analysis process. Cumulative probability distribution occurs over time. The cumulative probability distribution curve is a common, conventional method used to portray cost, schedule, and performance risk. Program Management Offices (PMO) can use cumulative probability distributions by determining an appropriate risk level (threshold) for the item and reading from the curve the corresponding target cost, schedule, or performance. This is a typical output of many automated risk tools. Appendix E contains a more detailed explanation of probability curves. The results of risk analysis are extremely valuable in presentations to decision-makers. The process of performing risk analysis generally provides an in-depth understanding of the sources and degree of risk and can be quickly portrayed in a few charts. This provides for much more effective presentation/communication to decision-makers of the program/project status. Section 6.5 has suggestions for communicating risk information.

Table 4.4-1. Watchlist Example.

EVENT/ITEM	AREA OF IMPACT	HANDLING ACTION
Loss of Competition	Production Cost	o Break Out o Qualify 2nd Source o Get Technical Data as a deliverable
Incomplete Logistic Support Analysis	Support Cost	o Contractor Support for 2-3 years o Warranty on High Risk Items o Logistics reviews
Immature Technical Data Package with many Engineering Changes for Design Fixes	Production Cost with High 1st Unit Cost and many ECPs	o Require Production Engineers on Contractor Design Team o Fixed Price Contract o Competition o Producibility Engineering Planning o Production Readiness Reviews
Long Lead Items Delayed	Production Schedule	o Get Early Identification of Long Lead Items o Contractor Emphasis on Early Delivery o Transfer or Leveling from less urgent programs o Buy a position in line for waiting

4.5 RISK HANDLING

Risk handling is the last critical element in the risk management process. It is the action of inaction taken to address the risk issues identified and evaluated in the risk assessment and risk analysis efforts. Generally, these actions fall into one of the following categories:

- o Avoidance
- o Control
- o Assumption
- o Transfer
- o Knowledge, Research and Skills

4.5.1 Risk Avoidance

The statement "I do not accept this option because of the potentially unfavorable results" reflects what is meant by risk avoidance. There are many situations where a lower risk choice is available from several alternatives. Selecting the lower risk choice represents a risk avoidance decision. This is typical of the evaluation criteria used in source selection. Certainly, not all risk should be avoided in all instances though. There are occasions where a higher risk choice can be deemed more appropriate because of design flexibility, Pre-Planned Product Improvements (P^3I), etc.

4.5.2 Risk Control

This is the most common of all risk handling techniques. It is typified by the statement "I am aware of the risk, and I will do my best to mitigate it's occurrence and effect." Risk control is the process of continually monitoring and correcting the condition of a program. This often involves the use of reviews, risk reduction milestones, development of fallback positions and similar management actions. Controlling risk involves the development of a risk reduction plan and then tracking to the plan. This includes not only the traditional cost and schedule plans, but also technical performance plans.

4.5.3 Risk Assumption

Risk Assumption is a conscious decision to accept the consequences should the event occur. Some amount of risk assumption is always present in acquisition programs. The program management office must determine the appropriate level of risk that can safely be assumed in each situation as it is presented. An example of risk assumption is permitting programs to have significant amounts of concurrency.

4.5.4 Risk Transfer

There are options available to program offices to reduce risk exposure by sharing risk. There are many ways to share risk with contractors. Type of contract, performance incentives, warranties, etc., are all forms of sharing risk with contractors. Note that many of these only share cost risk. Risk transfer is often beneficial to both the contractor and the government.

4.5.5 Knowledge, Research and Skills

While this is not a "true" risk handling technique, it does supply the other methods with valuable information. This is a continuing process that enables the participants to perform risk handling (with the other methods) with greater confidence. It consists of gathering additional information to further assess risk and develop contingency plans.

4.6 Summary

Risk handling methods are only constrained by the ingenuity and skills contained within the program office. While a conscious decision to ignore (assume) a risk is a viable option, an unconscious decision to do the same is not. A documented action with supporting rationale is recommended in all risk handling options.[3] Note that the risk handling techniques are not independent of each other. For example, assuming the risk involved is a concurrent program does not preclude the program manager from instituting measures to control inherent risk.

ENDNOTES / REFERENCES

1. Rudwick, B.; Lecture on Risk Management; DSMC Business Management Department; July 1988.

2. Caver, T.V.; Risk Management as a Means of Direction and Control; Fact Sheet Program Managers Notebook; DSMC; Fort Belvoir; No. 6.1; April 1985.

3. Technical Risk Assessment: The Status of Current DoD Efforts; U.S. General Accounting Office; April 1986.

CHAPTER 5

EXECUTING THE RISK MANAGEMENT PROCESS

5. EXECUTING THE RISK MANAGEMENT PROCESS

5. EXECUTING THE RISK MANAGEMENT PROCESS

5.1 INTRODUCTION

Having gained an understanding of the concepts of risk and the structure useful for executing risk management, it is logical to now present some specific techniques that apply to the process. All processes require two broad categories of action (Figure 5.1-1):

- o Planning
- o Execution.

This Chapter covers risk management techniques that have proven useful to both contractors and Government program offices in the execution of the risk management process. The planning issues were covered in Section 4.2 and will be reiterated in Chapter 6. There are basically seven steps in risk management as outlined below:

5.1.1 Evaluate the achievability of the proposed project against plan.

5.1.2 Identify the risk areas:

- o Develop a structure to systematically comb through the program and issues (i.e., WBS, checklist).
- o Interview subject area experts.
- o Review analogous system data.
- o Evaluate the program plans; do they coincide?
- o Examine lessons learned documents (i.e., transition templates, studies, etc.).

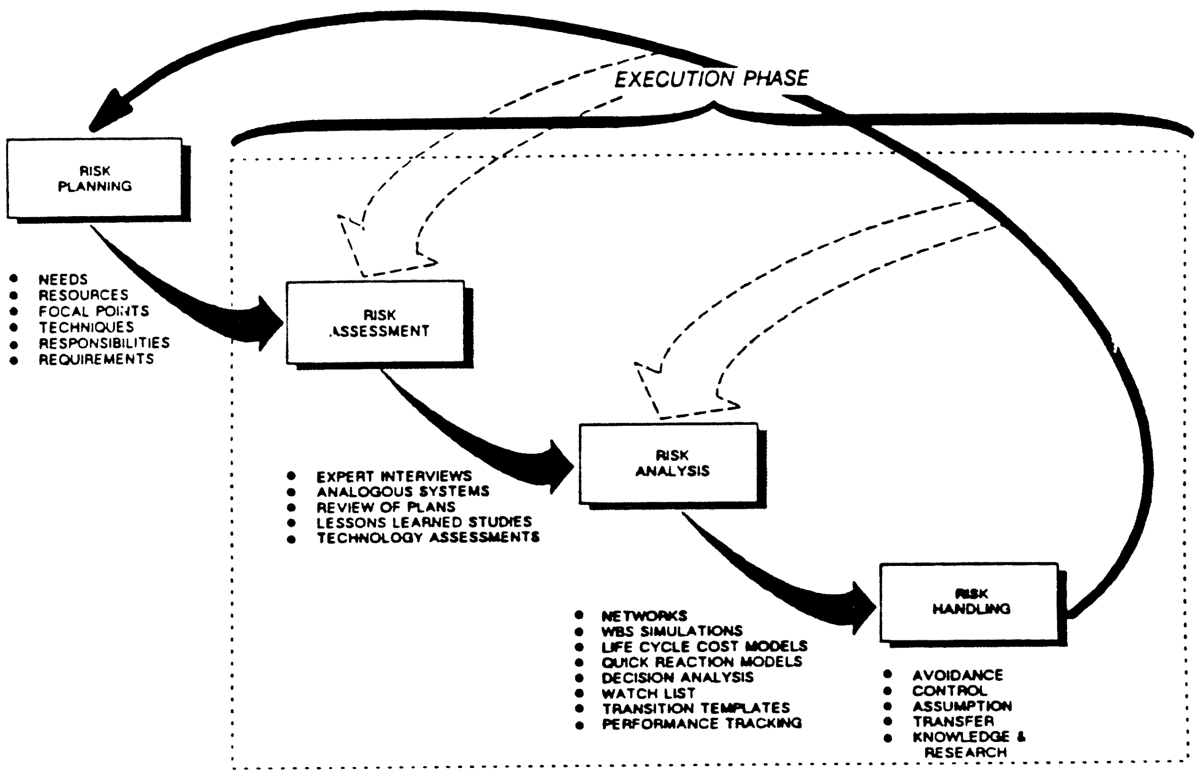
5.1.3 Quantify the risk areas:

- o Develop a consistent scheme for rating risk. Make it quantitative with qualitative backup.
- o Assess the likelihood of the risk occurring.
- o Assess the impact of cost/schedule/performance.

5.1.4 Document the risk areas:

- o Develop and maintain a management watchlist.
- o Develop an effective communication scheme so input from all functional areas is received.

Figure 5.1-1 The Risk Management Process



5.1.5 Utilize an analysis tool designed to meet your specific objectives. Examine the results:

- o In terms of performance/time/cost
- o By system/subsystem
- o Of funding profiles
- o Based on criticality
- o For consistency with analogous systems
- o Of "what-if" analysis.

5.1.6 Determine the appropriate handling option:

- o Avoid the risk.
- o Share the risk with another party.
- o Assume the risk.
- o Control the risk.

5.1.7 Implement the appropriate option.

The specific techniques for accomplishing these steps are contained in the following pages of this Chapter. Many of the techniques can be used as tools for multiple parts of the process. For example, an in-depth evaluation of a critical path network is very useful for steps 1, 2 and 5 above. It can be used to evaluate *and* identify risks in an approach, and serve as an excellent analysis tool. Figure 5.1-2 illustrates which techniques have application in more than one step of the process. The predominant application is represented be a "P" while secondary applications are represented by an "S".

5.2 EXPERT INTERVIEWS

5.2.1 General. One of the most critical elements or tasks in risk assessment is that of obtaining accurate judgments from technical experts. Unfortunately, this is an area where it is easy to make errors and, therefore, obtain information that is inaccurate. The interviewing of technical experts to gain information regarding risk is critical for two reasons. First, the information identifies those areas which are perceived as being risky (risk identification). Second, it provides the basis for taking the qualitative information and transforming it into quantitative risk estimates (risk quantification). Reliance on the advice of technical experts is mandatory since all information necessary for an accurate risk assessment usually can not be derived from previous program data. Obtaining information from experts, however, can be frustrating and often lead to less than optimum results.

Figure 5.1-2 Technique Application

RISK HANDLING	RISK ANALYSIS	RISK ASSESSMENT	RISK MANAGEMENT TECHNIQUE
S	S	P	Expert Interviews 5.2
S	S	P	Analogous Comparisons 5.3
		P	Plan Evaluation 5.4
S		P	Transition Templates 5.5
S	P		Decision Analysis 5.6
	P	S	Estimating Relationship 5.7
S	P	S	Network Analysis 5.8
S	P	S	Life Cycle Cost Analysis 5.9
S	P	S	Cost Risk / WBS Simulation Model 5.10
S	P		Risk Factors 5.11
S	P	S	Performance Tracking 5.13
S	P	S	Cost Performance Reports Analysis 5.13.1
S	S	P	Independent Technical Assessment 5.13.2
S	P	S	Independent Cost Estimates 5.13.3
P			Risk Handling Techniques 5.14
P			Risk Avoidance 5.14, 4.5.1
P			Risk Control 5.14, 4.5.2
P			Risk Assumption 5.14, 4.5.3
P			Risk Transfer 5.14, 4.5.4
P			Knowledge and Research 4.5.5

P = Predominant S = Secondary

Nearly all risk analysis techniques require some form of expert judgment input. This makes the acquisition of such judgments extremely important to the overall accuracy of the risk management effort. As already mentioned, this is a very difficult task to perform, and it is extremely hard to distinguish between "good" and "bad" judgments. This makes the approach and documentation even more important than usual. The program manager or risk analyst performing the effort is likely to get several divergent opinions from many "experts" and he/she must be able to defend the position taken.

5.2.2 Description of technique. The expert interview technique is relatively straightforward. Basically, it consists of identifying the appropriate expert(s) and methodically questioning them about the risks in their area of expertise as related to the program. There are many methods of accomplishing this as outlined in Appendix F. The technique can also be used with groups of experts.

The process is normally aimed at obtaining information on all five facets of risk.

5.2.3. When applicable. The technique is useful for virtually any program and is recommended for all programs. Expert interviews focus on extracting information about what the program risks are and their relative magnitude. It is most useful in the risk assessment portion of a risk management effort, but it also has application to the other processes as well. When questioning experts about the risks on a program, it is logical to pursue potential handling actions and alternatives as well as information pertaining to the potential impact.

5.2.4 Inputs and outputs. The technique has two prerequisites (required as input) for application. First, the interviewer must be prepared. The topic must be researched and an interview agenda thought through. Second, the interviewee must be willing to provide the information sought after and be willing to spend the necessary time required to divulge the information to the analyst or manager. The results (output) of such interviews can be qualitative, quantitative, or both. Expert interviews nearly always result in input that can be used in the formulation of a "watchlist." In fact, watchlists frequently evolve from the input of each "expert" functional manager on a program. Another frequently useful output is the formulation of a range of uncertainty or a probability density function (PDF) for use in any of several risk analysis tools. These can be in terms of cost, schedule, or performance.

5.2.5 Major steps in applying the technique. Since expert interviews result in a collection of subjective judgments, the only real "error" can be in the methodology for collecting the data. If it can be shown that the techniques for collecting the data are not adequate, then the entire risk assessment can become questionable. Unfortunately, there is no sure-fire technique for assuring that the data collected is the best possible. The only real assurance can be in the methodology used to collect the data. There are several methodologies available for collecting data, but many must be ruled out because of the time restrictions that usually exist. One combination (there probably are others just as good), which seems to work well, consists of the following five steps:

- Identify the right individual.
- Prepare for the interview.
- Target the interest area.
- Solicit judgments and general information.
- Quantify the information.

Each of these steps is discussed in the following paragraphs.

Identify the Right Individuals - It is extremely important to identify the correct subject or area expert. If there is any doubt about the level of expertise, it is worthwhile to identify one or two other candidates. It is relatively easy to make a mistake in this area by identifying an expert who knows only a portion of a given area. For example, if you are interested in knowing the risks involved in the test program for a particular project, you would want to talk to an expert in the test field. Someone who knows both hardware and software test procedures would be appropriate. The time spent up front identifying the individuals to be interviewed will be well spent. Preliminary phone screens are usually worthwhile. These usually only last about five minutes and can give the analyst a feel as to the level of expertise an individual has, as well as helping to focus the questions while preparing for the interview.

Prepare for the Interview - A lot of time can be saved for all parties if there has been adequate preparation by all involved. Some thought should be given as to what areas will be covered during the interview. The methodology for quantifying the expert judgment should be thoroughly understood and rehearsed if necessary. It is much easier to maintain control and direction during the interview, if there is an agenda or list of topics to be covered. It is also helpful to understand how the individual expert functions in the organization and how long he has been in the field. It is necessary to keep the ultimate goals of risk identification and quantification in mind while preparing for the interview. This means that there has to be some "open time" during the interview to allow the expert to give the interviewer his/her personal thoughts on areas which may be outside his/her field.

Target the Interest Area - The first portion of the actual interview should be to focus on the previously identified risk areas to obtain verification. This should be kept brief, except where there appears to be a conflict which would require additional information. Next, the interview should move to the individual's area of expertise. This will either confirm that the correct individual is being interviewed or will cause the focus of the interview to change. By targeting the interest area early, more time can be spent within the individual's area of expertise, if necessary, or the interview can be changed/ended saving valuable time if there has been an error in identifying the correct individual.

Solicit Judgments and General Information - It is important to let the expert have some time to discuss other areas of the program, if he/she desires, after completing the target interest areas. If nothing else, the information gained can be used when interviewing in another area to stimulate thoughts and generate another opinion. In many cases, an "outside" observer who is involved in the program can identify potential areas of conflict/risk which may not be apparent to the person working in the area where the potential conflict/risk resides. Much of the initial assessment is gained through just a few interviews. This information generally becomes more refined/

deleted/expanded as the subject experts are interviewed. Experience has shown that if the expert is cooperative, the information given (even that which is outside the area of expertise) is generally correct. Often additional clarification is required and the expert is unwilling to attempt a quantification, but the identification of risk is still valid.

Quantify the Information - This is the most sensitive aspect of any risk analysis. Once the risk areas have been identified, an estimate of their potential impact may be in terms of performance, cost, and schedule.

5.2.6 Use of results. Normally, the results of expert interviews feed other techniques or are used in the development of watchlists as described in Section 4.4.2.

5.2.7 Resource requirements. Interviewing experts requires two specific resources, the first of which is time. While this is one of the most common techniques in use for risk assessment, it is also one which is frequently misapplied because of time limitations. Planned interviews are sometimes shortened or skipped altogether in order to meet other obligations or deadlines by the interviewer and interviewee. A methodical examination of an entire program requires the time of many experts - both from the Government and contractor. The second resource requirement is an experienced interviewer. Frequently, experts do not give information which is readily usable for a watchlist or probability density function. Some skill is required to encourage the expert to divulge information in the right format. If an experienced interviewer is not available, the technique can still yield some valuable information if enough time is allocated.

5.2.8 Reliability. When conducted properly, expert interviews provide very reliable qualitative information. The transformation of that qualitative information into quantitative distributions or other measures depends on the skill of the interviewer. The technique is not without problems. Some typical problems that experienced risk analysts have had are listed below.

- Wrong expert identified
- Poor quality information obtained
- Unwillingness of the expert to share information
- Changing opinions
- Conflicting judgments.

5.3 ANALOGY COMPARISON/LESSONS LEARNED STUDIES

5.3.1 General. The "analogy comparison" and "lessons learned" techniques for risk identification and assessment are based on the idea that no new program, no matter how advanced or unique, represents a totally new system. Most "new" programs originated or evolved from already existing programs, or simply represent a new combination of existing components or subsystems. A logical extension of this premise is that key insights can be gained concerning the various aspects of a current program's risk, by examining the successes, failures, problems, and solutions of similar existing or past programs. The experience and knowledge gained, or "lessons learned," can be applied to the task of identifying potential risk in a program and developing a strategy to handle that risk.

5.3.2 Description of technique. The analogy comparison and lesson learned techniques involve the identification of past or existing programs that are similar to the Program Management Office (PMO) effort and the review and use of data from these programs in the PMO risk management process. The term "similar" refers to the commonality of the variety of characteristics which defines a program. The analogy may be similar in technology, function, acquisition strategy, or manufacturing process. The key is to understand the relationship between the program characteristics and the particular aspect of the program being examined. For example, in many system developments, historic cost data shows a strong positive relationship with technical complexity. Thus when looking for a program in which to analyze cost risk for comparison, it makes sense to examine data from programs with similar function, technology, and technical complexity. The use of data or lessons learned from past programs may be applicable at the system, subsystem or component level. For example, though an existing system's function and quantity produced differ, its processor may be similar in performance characteristics to a current program and thus a valid basis for analogy comparison. Several different programs may be used for comparison to the current project at various levels of the end item.

5.3.3 When applicable. The application of documented lessons learned or the comparison of old or existing programs to new programs is useful in all phases and aspects of a program. In any situation in which historic data is useful in predicting or anticipating the future, the analogy comparison and lessons learned technique can provide valuable insights into the risk associated with a program. These techniques are especially valuable when a new system is primarily a new combination of existing subsystems, equipment, or components for which recent and complete historical program data is available. When properly done and documented, analogy comparison provides a good understanding of how the program characteristics affect the risk identified and provide a necessary input to many other risk techniques.

5.3.4 Inputs and outputs. There are three types of data required for use of the technique:

- o Description and program characteristics of the new system and its components
- o Description and program characteristics of the existing or past programs and their components
- o Detailed data for the prior system being reviewed (cost, schedule, performance, etc).

The descriptive data and the program characteristics information are needed to draw valid analogies between the current and past programs. The detailed data is required to evaluate and understand program risks, and their potential effect on the current project. Often technical specialists are needed to help make appropriate comparisons and to help extrapolate or adjust the data from old programs to make inferences about new programs. Technical or program judgments may be needed to adjust findings and data for differences in complexity, performance, physical characteristics, or acquisition approaches.

The output from the examination of analogous programs and lessons learned typically becomes the input to other risk assessment and analysis techniques. The review of program lessons learned reports can identify a number of problems to be integrated into a program's watchlist. The length and volatility of past flight test programs is information that would aid in the development of realistic durations in a network analysis of a new program's test schedule. Data from the review of lessons learned and past analogous programs becomes the source of information for the conduct of risk assessment, analysis, and handling techniques.

5.3.5 Major steps in applying the technique. The major steps in the use of analogous system data and lessons learned include the identification of analogous programs, data collection, and analysis of the data gathered. Figure 5.3-1 shows a further breakdown of this process.

The first step is to determine the information needs in this phase of the risk management process. This could vary from wanting to assess the risk involved with the development of a custom computer chip for a new application to a broad goal of identifying all of the major risks associated with a program.

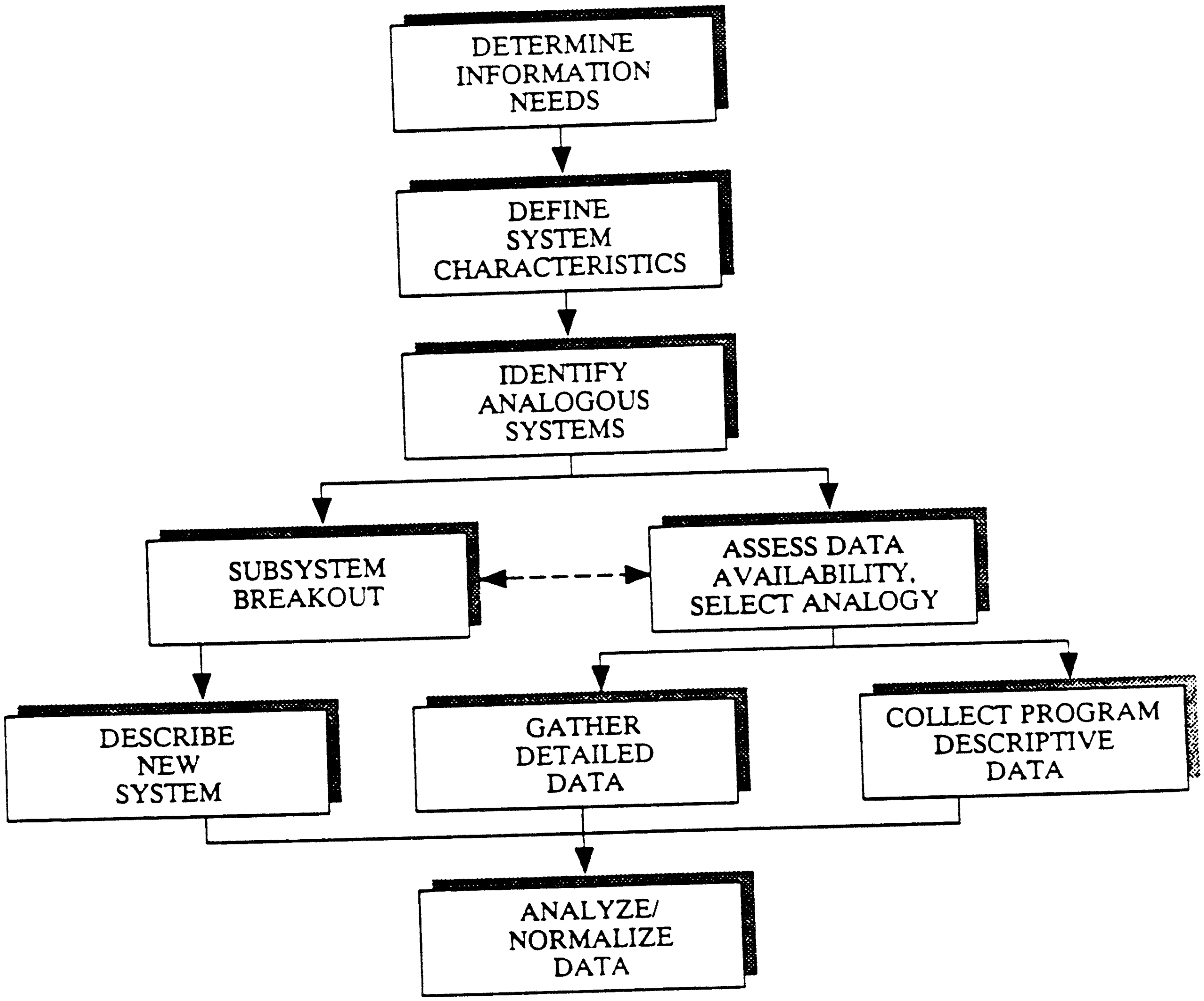
The second step is to define the basic characteristics of the new system. This is necessary in order to identify past programs that are similar in technology, function, or design. With the new system generally defined, the analyst can begin to identify programs with similar attributes for comparison and analysis.

The next steps in this process, being interdependent, are generally done in parallel. The key to the usefulness of analogy comparison is the availability of data on past programs. The new system is broken down into logical components for comparison, while assessing the availability of historical data. There is no use in analyzing a system at a detailed component level against past efforts if that same level of detailed information is not available in past programs. Based on the availability of data, the information needs of the process, and the logical structure of the program, analogous systems are selected and data gathered.

The data gathered for comparison includes the detailed information being analyzed, as well as the general characteristics and descriptions of the past programs. The general program descriptive data is essential to ensure proper analogies are being drawn and a clear understanding of the relationship between these characteristics and the detailed data being gathered is understood. For the analogy to be valid, there must be some relationship between the characteristic being used to make comparisons and the specific aspect of the program being examined. For example, if there is no basis for relating weight to schedule, weight of the system is a suspect basis for drawing an analogy while doing a schedule assessment.

Often the data collection process and initial assessment lead to a further definition of the system for the purposes of comparison. After this has been accomplished, the last step in the process is the analysis and normalization of the historic data. Comparisons to older systems may not be exact or the data may need to be adjusted to be used as a basis for estimating the future. For example, in analogy based cost estimating, cost data must be adjusted for inflation, overhead rates, or G & A for accurate comparison. Technical assistance is frequently needed to adjust the data for differences in past versus current programs. The desired output is some insight into the cost, schedule, and technical risks of a program based on observations of similar past programs.

Figure 5.3-1 Analogy Comparison



5.3.6 Use of results. As stated earlier, the output from analogy comparison or the review of lessons learned typically feed other risk techniques. The results may provide a checklist of factors to monitor for the development of problems or a range of cost factors for use in estimating (for example, software lines of code). The results of analogy comparison and lessons learned are risk information. Whether the information is used in a detailed estimate, technology tradeoff study, or at a system level for a quick test of reasonableness, the results are intended to provide the analyst with information on which to conduct analyses and ultimately base decisions.

5.3.7 Resource requirements. The use of analogous data and lessons learned studies to gather risk data is a relatively easy task. The selection of proper comparisons and the analysis of the data gathered may require some technical assistance and judgment, but probably not beyond the capabilities of the PMO. The time and effort to accomplish an analogy comparison, however, can vary widely. The resources needed are dependent on the depth of the data gathering, the number of different programs, and the availability of historic data. Much effort can be expended gathering a little information. That is why an initial assessment of data availability is important in the selection of analogous programs for comparison.

5.3.8 Reliability. There are two limitations to the use of analogy comparisons and lessons learned. The first, the availability of data, has already been discussed. The absence of program characteristics or detailed data about the new or old system limits the usefulness of the data collected. The second limitation deals with the accuracy of the analogy drawn. An older system may be somewhat similar, but rapid changes in technology, manufacturing, etc., may make comparisons to past programs inappropriate.

5.4 PLAN EVALUATION

5.4.1 General. This technique is directed at highlighting and isolating risks caused by disparities in planning. It evaluates program plans for contradictions and voids. The term "plan" as used in this case means the traditional formal plans to govern the acquisition of a major system. These include:

- Program Management Plan (PMP)
- Systems Engineering Management Plan (SEMP)
- Acquisition Plan (AP)
- Test and Evaluation Master Plan (TEMP)
- Manufacturing Plan (MP)

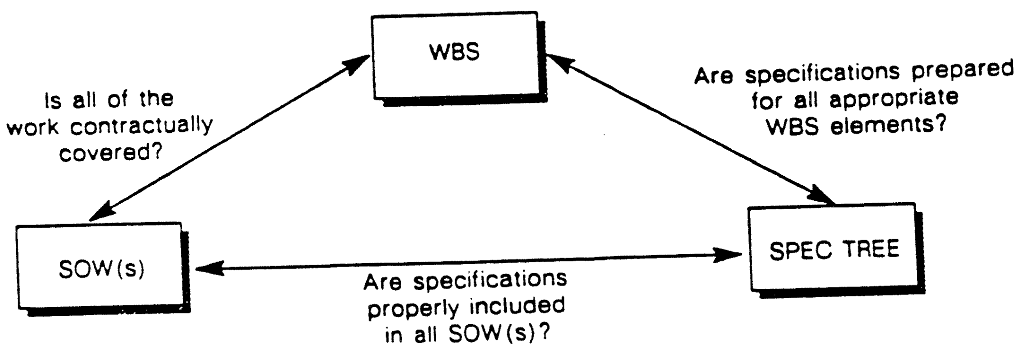
- Integrated Logistics Support Plan (ILSP).

Other documents, not normally thought of as plans, but key to the success of a program are:

- Work Breakdown Structure (WBS) Index and Dictionary
- Specifications and the Specification Tree
- Statements of Work (SOW).

While the first group of plans documents the steps in the execution of the program, the latter represent the absolutely critical communication with the contractor(s) about what is to be done. Flaws, inconsistencies, contradictions, and voids in these documents guarantee program problems and introduce significant risk. Figure 5.4-1 illustrates the linkage between the three key documents.

Figure 5.4-1 Plan Evaluation Technique



5.4.2 Description of technique. This technique simply suggests a thorough recurring review of all plans:

- Internally for correctness, completeness, and currency
- Cross check for consistency.

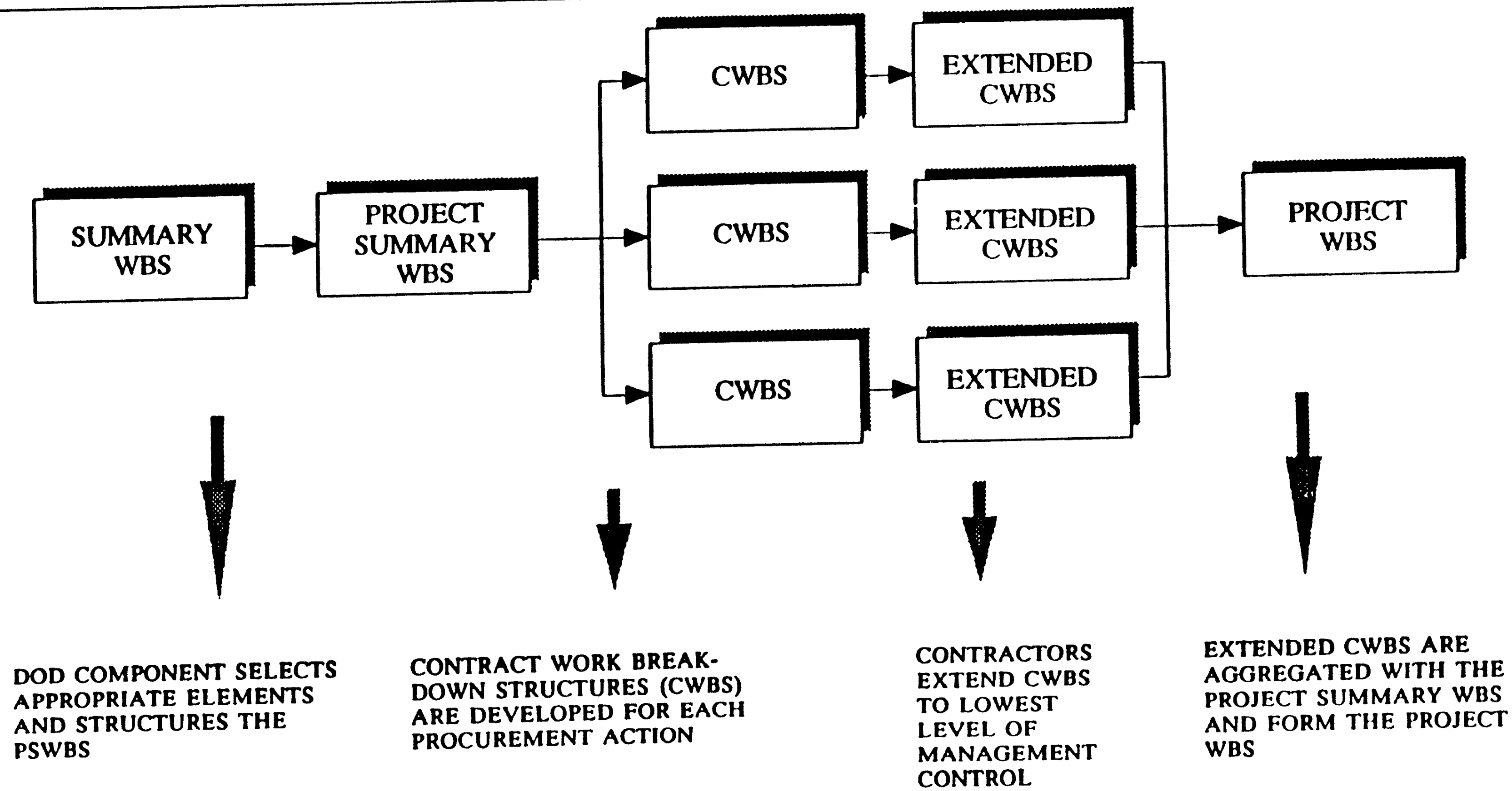
Using the Work Breakdown Structure for risk identification - The proper development of a WBS represents in itself a major step in risk avoidance. It constitutes much of the program definition. Its quality, indeed its very existence, provides the framework for planning that sets the standard for the future of the program. The end result of the WBS development process is the Project WBS. A careful questioning of the Project WBS is appropriate.

- Are all elements of the WBS necessary and sufficient?
- Is there a WBS dictionary and does it adequately explain the content of each element?
- Does the WBS represent what is to be done rather than who is to do it?
- Are all elements of the Project WBS present?
  - Summary WBS
  - Project Summary WBS
  - Contract WBS
  - Contractor Extension of the Contract WBS
- Is the procurement strategy reflected in the Project WBS?
- Is there any "work" to be done that is not in the WBS?

The WBS offers a framework for organizing and displaying risk factors. The technique of downward allocation and upward summarization through the WBS can be used to highlight discrepancies in most of the program's performance parameters, such as weight, electrical power, cooling requirements, system reliability, and cost. The WBS provides a sensible structure for treating technical risk. A systematic review of each WBS element for risk identification and preliminary rating as discussed in Section 4.3 will yield much information to the risk analyst. The relationship between the Work Breakdown Structure and the Specification Tree is so important that mapping the relationship is a valuable exercise for the risk analyst. The mapping will highlight inconsistencies between the "work to be done" and the "performance to be achieved."

Figure 5.4-2 illustrates the fact that the project WBS eventually becomes the aggregate of contract WBSs and the contractor's extension thereof, which includes subcontractor WBSs. The risk analyst should review the WBS with the question "Who is doing what?" as a test of reasonableness of the procurement/ contracting strategy. Finally, the WBS represents the framework for cost and schedule performance. A survey of both the cost and the schedule reporting against the WBS identifies possible blind spots in cost and schedule information. As part of this survey, the analyst can gain valuable insights by comparing the numbering schemes for the WBS, the scheduling system(s), and the cost reporting system(s).

Figure 5.4-2 WBS Preparation/Development



Ease of translation between and within each of these numbering systems is an indicator of how well traceability among the WBS, schedules, and cost data can be maintained. Incompatibility introduces management risk into the program.

Using Specifications and the Specification Tree for Risk Identification - Some of the discussion above deals with the very important relationship between the WBS and the Spec Tree, and the need for compatibility. When that compatibility exists, it is possible to relate the performance to be achieved to the work to be done. Since the specifications represent the source of all technical performance requirements, they are the single most important source of information for the risk analyst attempting to identify, organize, and display items of technical risk. Each performance parameter of a given WBS element represents a possible focus for an expert interview on technical risk. As with the WBS, a survey of the specifications and the specification tree is appropriate for risk identification.

- Does the Spec Tree overlay the WBS so that performance requirements are specified for "whole" WBS elements?

- Are all performance parameters identified even though they may not be specified (i.e., given a discrete value)?

- Is it possible to sensibly discuss the risk of achieving the specified value for the performance parameter?

- Is there a technical performance measurement scheme for each performance parameter?

Using Statement(s) of Work for Risk Identification - The Statement of Work is the single most important communication between the program manager (who wants results) and the contractor (who has to produce the results). If the WBS and the specifications are complete and well done, SOWs are fairly straightforward. The risk analyst is primarily searching for gaps in coverage, (i.e., work and performance requirements that have not been assigned to someone (the contractor)).

- Do the SOWs cover whole pieces of the WBS that can be evaluated against whole specifications?

- Do the SOWs represent work that can be contracted in a straightforward manner, or will the contracts be politically, legally, or contractually difficult to execute and manage?

- Is all of the work contractually covered?

- Are the SOW requirements properly related to the specifications?

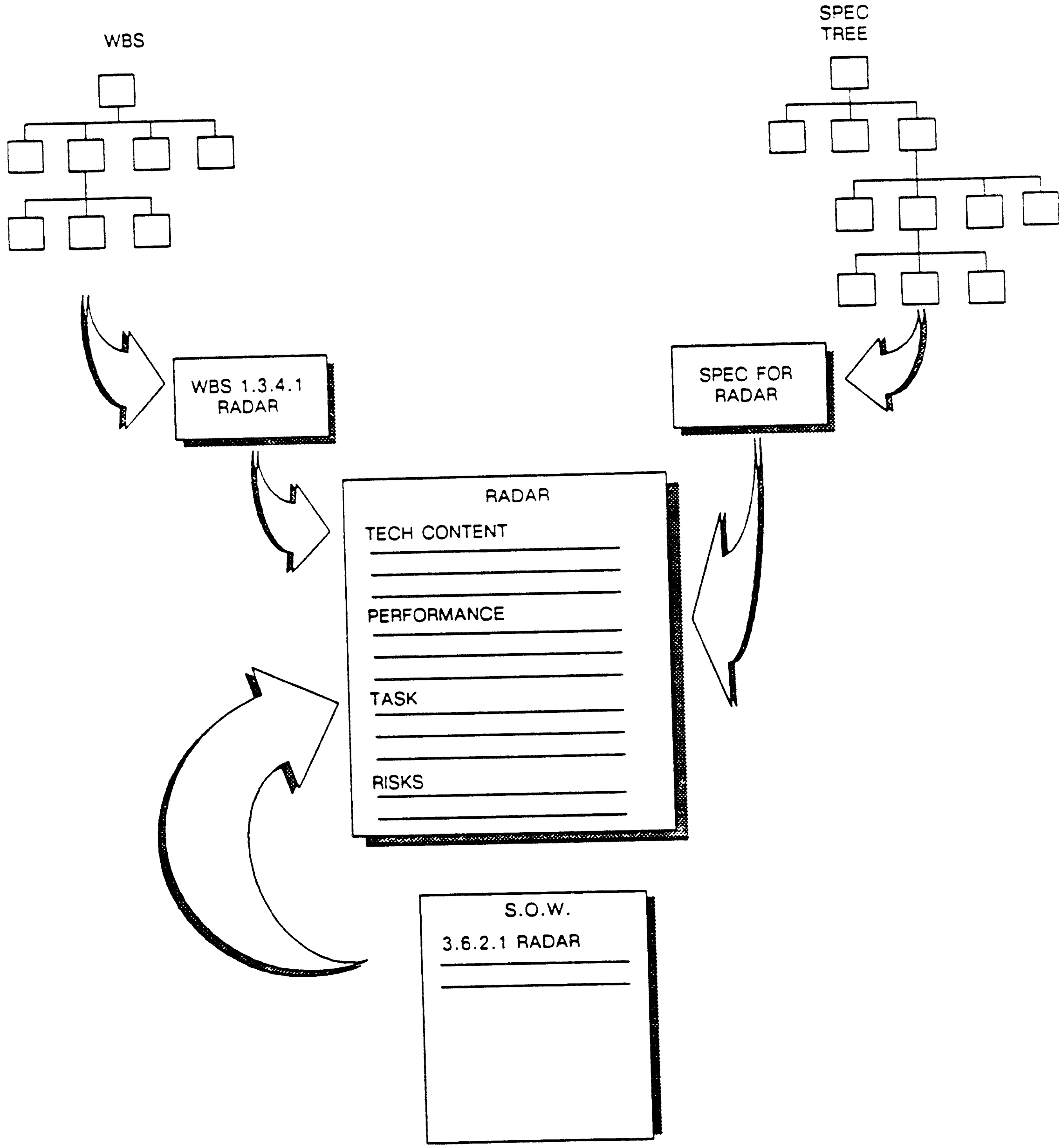
Developing a Technical Risk Dictionary - The concept of dictionaries is understood and fairly well institutionalized in FAA acquisition program offices. The WBS dictionary is well known and well established. More recently, program offices are using the idea of a schedule dictionary to provide the definition of the activities in the program schedule and the assumption that leads to their durations.

This Section 5.4.2 has thus far dealt with a body of information that represents the documented description of the sum and substance of an acquisition program. A technical risk dictionary as conceptualized in Figure 5.4-3 offers a way for the risk analyst to gather this information in a single place in order to facilitate the risk identification/definition process. The creation of a technical risk dictionary would have been a formidable editorial task until recently. Current word processing and database management software should make the bulk of the task one of electronic cut and paste. Indeed, if document and paragraph numbering are done with a view to interchangeability of data, the technical risk dictionary could be quickly created with a single utility program. This of course applies to the technical content, performance, and task sections of the dictionary which serve as background material for the risk section. The risk section represents original thought contained only in this document.

Defense Systems Management College is engaged in an effort to develop automated tools for the program manager. Two of these, the Automated Program Planning Documentation Model (APPDM) and the Procurement Document Generator (PDG), are intended to aid in the creation and maintenance of the large volumes of textual material required by a typical program office. One of the elements of APPDM is a model Risk Management Plan (discussed in Section 4.2.3). An extension of this capability to produce a technical risk dictionary is easily within reach.

Using Other Plans for Risk Identification - In Section 4.3.1, the use of a Top Level Risk Matrix to highlight and isolate risks was discussed. It relies heavily on goal definition and strategy development. The presumption is that the strategies expressed in the program plans are directed at meeting the program goals. Comparing the two is a way to identify risks. The same thought process can be applied to produce lower level risk matrices for each of the respective plans (e.g., the TEMP in Full Scale Development (FSD)). Some particularly astute program managers are formally including discussions of risk within the program plans (as they should be), either as a section in each chapter or as a separate chapter.

Figure 5.4-3 Technical Risk Dictionary



Summary. In the ideal world, where a program management office is staffed with seasoned professionals of long tenure, the Plan Evaluation technique would produce very little results for a large effort. All of the planning documents would have been created in the proper sequence, each with reference to all that preceded it. Eminently logical contracts would have been let with masterful work statements and perfect specifications. In reality, tenure in a program office is very short and planning documents are prepared simultaneously or out of order, by a cast of people having a wide range of experience, both totally and within the particular program. Corporate memory is very short and in the early stages when most of the planning is accomplished, most program management offices are grossly undermanned. The Plan Evaluation technique, therefore, is very useful in program management.

5.4.3 When applicable. This technique is specifically directed at risk identification. It is best used for technical, programmatic, and supportability risk identification. Its utility for cost and schedule risk is considerably less. This technique, however, could indicate any missing information concerning deliverables which would impact cost and schedule risks. It is most applicable to the full scale development and production phases of a program. As a risk identification technique, it requires the existence of the plans to be evaluated. As a risk avoidance tool, it can be used during the program planning process.

5.4.4 Inputs and outputs. The technique operates on the collective body of documentation broadly referred to as "program plans." This includes primarily those documents listed in Section 5.4.1. The output of the technique will typically be:

- o A top level risk matrix
- o Lower level risk matrices
- o A technical risk dictionary
- o Updated versions of the program plans.

5.4.5 Major steps in applying the technique

- o Evaluate WBS for completeness and correctness.
- o Evaluate Spec Tree for completeness, correctness, and compatibility with WBS.
- o Evaluate SOWs for completeness, correctness, compatibility with WBS, and inclusion of spec references.
- o Develop lower level risk matrix for all other plans.

5.4.6 Use of results. The results of this technique are best used to improve the quality and reduce the risks contained in the program plans. The technique also produces descriptive documentation of the technical, performance, programmatic, and supportability risks associated with the program. The technical risk dictionary describes the technical risks and isolates their location. The program manager should use this technique to produce a single, more or less "official," list of program risks that will receive active management attention (i.e., a watchlist).

5.4.7 Resource requirements. This technique requires a great deal of thought. It requires experienced, knowledgeable personnel who are intimately familiar with the content of the total program. The deputy program manager leading a small team of senior individuals probably represents the best means of executing this technique.

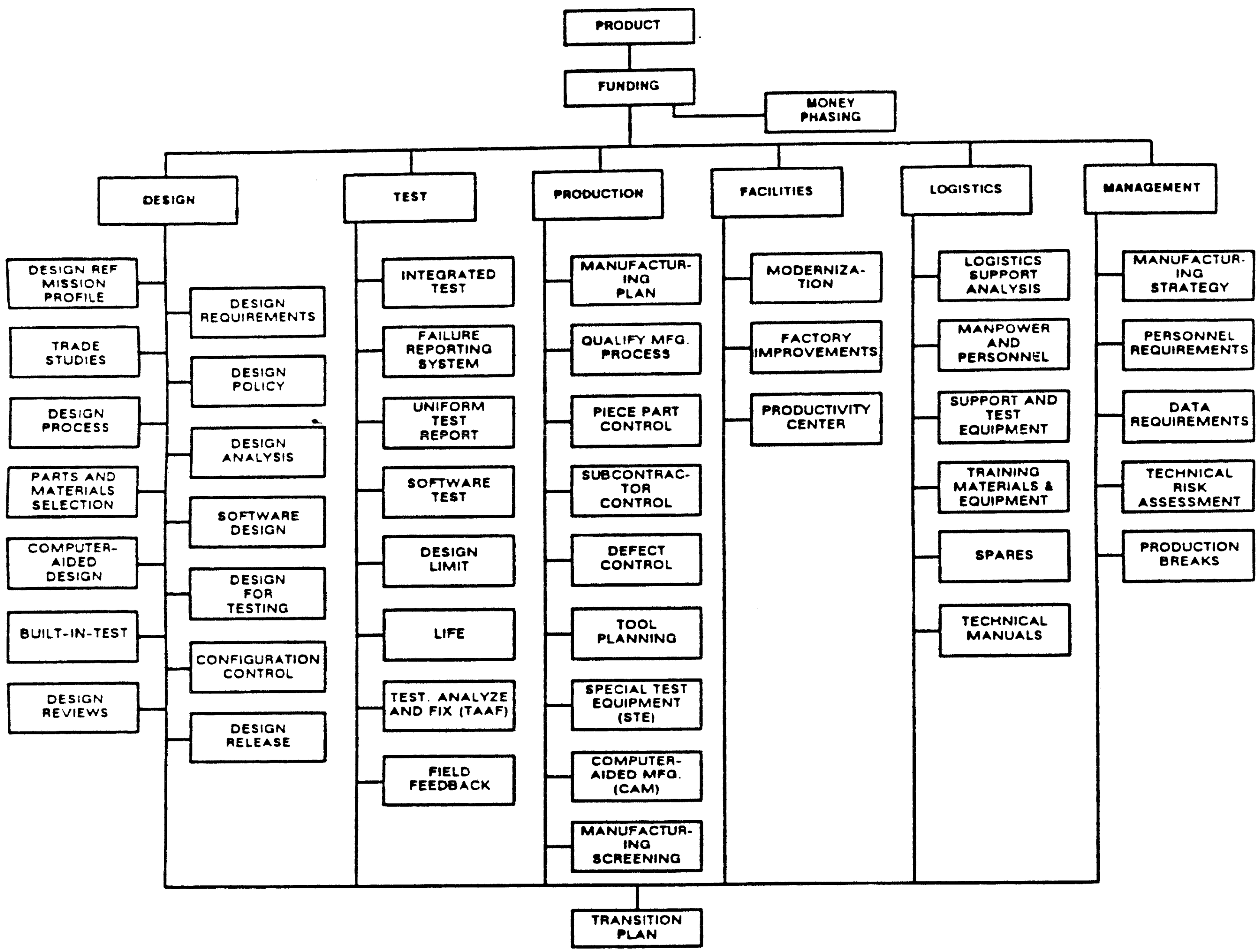
5.4.8 Reliability. The reliability of this technique is driven by the completeness and farsightedness of the program plans. The relationship is an inverse one - the better the plans, the fewer the planning risks uncovered. The major caution for the user of this technique is not to try to force detailed program definition too early. Some inconsistencies exist because of poor planning, others due to a legitimate lack of information.

5.5 TRANSITION TEMPLATES

5.5.1 General. This technique is based on the work performed by the Task Force on "Transition from Development to Production," which resulted in the publication of DoD 4245.7-M, "Transition from Development to Production ... Solving the Risk Equation," in September 1985. This manual is recommended reading for all program managers. It includes extensive work on the identification of program pitfalls based on solid experience. The focus of the book is on disciplined engineering and its impact on the entire management process through all phases of a program. There is also a companion manual, NAVSO P-6671, "Best Practices, How to Avoid Surprises in the World's Most Complicated Technical Process," November 1985. This second document identifies specific questionable practices in use and their potentially adverse consequences. The book then describes the "best practices" which avoid or alleviate their consequences.

5.5.2 Description of technique. The technique consists of examining a series of "templates" that cover specific areas that may present technical risk to a program. Each template examines an area of risk and then describes methods for avoiding or reducing that risk. Much of the description of the risk and the solution is based on lessons learned from other programs. The areas covered by the templates are illustrated in Figure 5.5-1.

Figure 5.5-1 Critical Path Templates



5.5.3 When applicable. This technique should be used for most programs - either independently or in conjunction with another technique. The information contained within the templates is extremely valuable to all program managers because it is based on actual experiences. The information can be useful for any size program at any phase of development. Since the technique views the acquisition process as a complete process (that is design, test, and production are integral parts of a whole system), the solutions presented reflect the interdependency of each part of the development cycle. In other words, a conscious effort is made to present a solution that lowers the total risk for the entire program - not just the short term problem.

5.5.4 Inputs and outputs. Since the technique is not a model, it requires no formal inputs. What it does require is discipline. Some amount of time must be spent in reading the manual and using it to examine risk within a given program. A practical output of the technique is the watchlist which was described in Section 4.4.2.

5.5.5 Major steps in applying the technique. Since the templates cover areas common to nearly every program, it is suggested that each template be utilized. After reading the material, individuals and/or groups should evaluate themselves in relationship to the solutions/risk mitigating actions suggested in the template. For those areas that are potential "show stoppers," a separate watchlist should be developed and maintained. A semi-annual review of all templates is recommended with updates as the program progresses.

5.5.6 Use of results. The results from the transition templates can be used in several ways: (1) They can be used in presentations to higher levels of authority; (2) They can be used to influence the contractor's current level of activity in an area; and (3) They can be used for continued monitoring of progress in each element.

5.5.7 Resource requirements. Generally, the templates require that the program manager be involved in the risk identification process. Inputs should be provided by all functional managers. The use of the templates is not intended to require substantial special skills or extra resources.

5.5.8 Reliability. Two cautions are applicable when using this technique:

- o Do not assume that the templates contain all possible technical risks within a given area. While the common problems are identified, this is not an exhaustive list.

- o The templates do not contain information regarding several of the programmatic risk areas that should also be examined for risk.

5.6 DECISION ANALYSIS

5.6.1 General. Decision analysis can be used to determine optional strategies when a decision maker is faced with several decision alternatives and an uncertain or risk-filled pattern of future events. Before selecting a specific decision analysis technique, the type of decision-making situation that will be encountered must be considered. The classification method for decision-making situations is based upon the knowledge the decision maker has about those future events which are beyond the decision maker's control (known as states of nature). With this in mind, there are two types of decision-making situations.

(1) Decision-making under certainty - The process of choosing a decision alternative when the states of nature are known.

(2) Decision-making under uncertainty - The process of choosing a decision alternative where the states of nature are unknown.

The decision analysis techniques appropriate for risk assessment are those which take into consideration that the decisions are made under uncertainty.

In many situations where good probability estimates can be developed for the states of nature, the Expected Monetary Value (EMV) method is a popular technique for making decisions. In some situations of decision-making under uncertainty, the decision-maker may have very little confidence in his or her ability to assess the probabilities of the various states of nature. In such cases, the decision-maker might prefer to choose a decision criterion that does not require any knowledge of the probabilities of the states of nature.

5.6.2 Description of technique. In general, there are three steps in formulating a decision theory problem using the EMV method.

(1) The initial step in the decision theory approach is the definition of the problem.

(2) For a given problem situation, identify the alternatives that may be considered by the decision-maker. The alternatives which are feasible to the decision-maker may be denoted by di.

(3) Identify those relevant future events which might occur and are beyond the control of the decision-maker. These are referred to as states of nature and may be denoted by sj.

In decision theory terminology, a particular outcome resulting from a certain decision and the occurrence of a particular state of nature is referred to as the payoff. V(di,sj) denotes the payoff associated with decision alternative di and state of nature sj.

5.6.3 When applicable. The EMV model is applicable during any phase of a program, although it would typically be generated at the onset of the program to identify the probabilistic courses of action the program may take. Since decision analysis models can be portrayed as decision trees, they can be applied to network analysis. Probabilistic branching in a network is an example of using decision analysis in a network analysis framework.

5.6.4 Inputs and outputs. The inputs to the EMV model consist of the decision alternatives to be considered, the states of nature associated with the decision alternatives, and the probability of occurrence for each state of nature. The outputs of the EMV method are the expected monetary values for each of the decision alternatives under consideration.

5.6.5 Major steps in applying the technique. The Expected Monetary Value criterion requires that the analyst compute the expected value for each alternative and then select the alternative yielding the best expected value. The expected monetary value of a decision alternative is the sum of the product of the payoffs with their respective probabilities. The percentage value for a payoff is the probability of the associated state of nature and, therefore, the probability the payoff occurs.

5.6.6 Use of results. Given the expected monetary values of the decision alternatives, the analyst's selection of the appropriate alternative is predicated on whether the objective is to maximize profit or to minimize cost. When the difference between one or more decision alternatives is small, other programmatic factors may be taken into consideration when making the decision.

5.6.7 Resource requirements. With respect to resource requirements, the EMV technique is simplistic and can usually be easily calculated once the inputs to the model have been obtained. As the decision problem being modeled becomes more complex, with an increasing number of decision alternatives and states of nature, the time required to create a decision table or a decision tree will also increase.

5.6.8 Reliability of results. One of the most attractive features of the EMV method of decision analysis is that once the respective inputs to the model have been obtained, there is no ambiguity insofar as the analysis is concerned. The reliability of the results are predicated on the validity of the inputs to the model; that is, with what degree of accuracy the analyst/experts can define all the relevant decision alternatives, states of nature, and respective probabilities. Another significant benefit of the EMV method is that it diagrammatically portrays the decision alternatives and the associated analysis, making it easier to conceptually understand the problem, the alternatives, and the analysis.

5.7 ESTIMATING RELATIONSHIP

5.7.1 General. The Estimating Relationship method enables program office personnel to evaluate a program and, based thereon, use an equation to determine an appropriate management reserve or risk funds budget. When using this method, the management reserve funds represent the amount of funding, over and above that determined by cost analysis alone, required for work associated with unanticipated risks. This method was originally developed and is still used for contract, not program costs. The management reserve funds requirement computed is usually expressed as a percentage of the baseline cost estimate. The technique is called an estimating relationship method because it uses some of the same techniques associated with cost estimating relationships (CERs), used in parametric cost estimating.

5.7.2 Description of technique. The cost estimating relationship method is based on the observation that costs of systems seem to correlate with design or performance variables. The independent variables, often called explanatory variables, are analyzed using regression analysis to describe the underlying mechanism relating such variables to cost. This approach to cost estimating, also called parametric cost estimating, is widely accepted and, even for complex functions, is easy to apply. This ease of application makes it natural to attempt to use the same techniques to estimate the costs resulting from risks. The approach attempts to discover acquisition program or contract characteristics, as explanatory variables, which can then be correlated with the historically demonstrated need for management reserve or risk funds. Regression analysis using "actual" management reserve funds from past programs, expressed as a percent of total costs, is performed to develop an equation with which to estimate management reserve funding requirements for a new program, not in a database.

The application of this technique is described in Section 5.7.5. In the example describing the application of this technique, four program and prime contractor characteristics, which are known to affect the level of uncertainty, are evaluated by PMO personnel. Each characteristic is assigned a value based on a different scale provided for each characteristic. The four characteristics used are *Engineering Complexity* (zero to five), *Contractor Proficiency/ Experience* (zero to three), *Degree of System Definition* (zero to three), and *Multiple Users* (zero or one). The sum of these numerics is entered as the value X, in an estimating equation such as Equation 5.7-1.

Equation 5.7-1

$$y = (0.192 - 0.037X + .009X^2) \times 100$$

This formula determines the percentage management reserve requirement, y. The particular model shown in this example is usable only for X values between 2 and 10. Lower values indicate essentially no need for management reserve funds.

5.7.3 When applicable. This method of estimating the additional funding needed to cover anticipated risks can only be used if the research has already been done to establish a valid historical relationship between the key program or contract characteristics of similar programs, and management reserve funding requirements. The method is most applicable in the circumstances where good historical program description and management reserve funding requirements are available for several similar programs. If the required risk funding estimating relationship is available, this method has the advantage that it is both quick and easy to apply.

5.7.4 Inputs and outputs. The inputs to an estimating relationship model, such as Equation 5.7-1, are judgment values characterizing the four program or contract factors described in Section 5.7.2. The estimating relationship method provides a percentage figure to be applied to estimated baseline cost to be used to determine the amount of total or contract management reserve funds required. This percentage value is computed using an equation like Equation 5.7-1, with the X value being the sum of the factor values determined by PMO personnel.

5.7.5 Major steps in applying the technique. Assuming an appropriate management reserve estimating equation is not available, the first major step in using this method and, by far the most difficult, is developing an equation relating program characteristics to management reserve funding requirements. The most difficult part of this step is finding valid historical characteristic and management reserve funding data for enough similar programs to carry out regression analysis. Data from at least ten past programs should be used to develop an estimating relationship equation. The second part of Step 1 is to determine the program or contract characteristics which drive management reserve funding requirements, and for which historical data has been collected. After the historical data has been collected, it is relatively simple to use regression analysis to identify these characteristics. The summing of judgement level values for each of four program characteristics, as done for the equation described in Section 5.7.2, is only one way to develop one or more independent variables for an estimating relationship for management reserve funding requirements. Geometric mean or weighted average techniques could also be used. Multiple regression analysis techniques frequently are used for parametric cost estimating.

The second and final major step in using this method is to use the prediction equation derived through regression analysis and the new program or contract characteristic information, to compute a percent value for the additional management reserve funds needed to cover anticipated additional costs associated with risk. It may be useful to vary the program description characteristic data somewhat and recompute the estimating equation to assess the impact of such changes in the computed management reserve requirements. This sensitivity analysis is usually prudent because of the uncertainty associated with the predicted program or contract characteristics.

5.7.6 Use of results. Using this method, the percent value of the estimated contract or program cost is computed and added to the basic cost estimate to cover funds needed for risk. As an example, if the contract cost estimate was $100M and the prediction equation provided a result of 30 percent, $30 million dollars would be added for risk, making the total estimated contract cost $130M.

5.7.7 Resource requirements. Once a suitable management reserve funding requirement prediction equation is available, only a few hours are required to apply this method. Most of the effort required involves interviewing PMO personnel to obtain their judgments on the contract or program characteristic values to be used. If a prediction equation has to be developed, one to three months of a skilled analyst's time would be required, depending on the difficulty incurred in acquiring the needed data. It is possible that the required data may not be available, and that no amount of effort would result in the development of a satisfactory prediction equation.

5.7.8 Reliability. This method provides results that significantly increase cost estimates (based primarily on the extrapolation of historical data which may include costs for risks that have already been experienced) to allow for risk. Because the additional funds are based primarily on judgment values, they are subject to question. If this technique is to be used, it would always be prudent for a PMO to have the method, including the prediction equation to be used, reviewed and accepted by higher headquarters, before using it as the basis for a sizable request for additional funds to cover risks. The method can only be used where adequate historical data is available to develop a sound management reserve fund requirement prediction equation.

5.8 NETWORK ANALYSIS

5.8.1 General. Many FAA program managers are familiar with the concept of network based scheduling as a program management tool. Program managers are fully aware that a quality schedule is critical for the effective planning, implementing, and controlling of any program. A quality schedule is essentially a plan of action that is objective oriented. It includes activities/events which must be accomplished to achieve the desired objective. Network based scheduling or networking formalizes the scheduling process and results in a graphical output, which displays not only the activities which must be accomplished to complete the program, but also the relationships among the activities (that is, which activities precede, succeed, or are parallel to other activities). The utility of networking in general includes:

- o Focusing the attention of all management levels during the planning phase
- o Estimating program completion date
- o Displaying the scope of the program
- o Assessing resource requirements
- o Facilitating "what if" exercises
- o Highlighting critical activities
- o Evaluating performance.

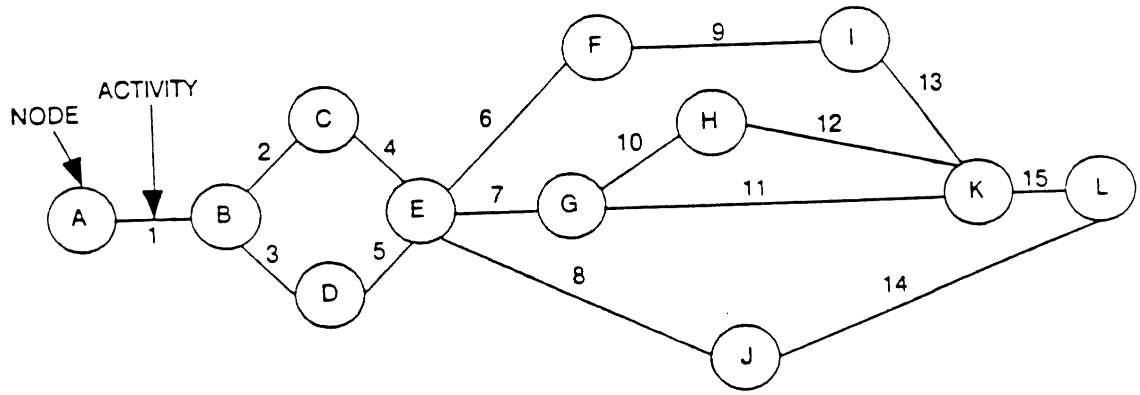
The keys for successful network development are:

- o Determine the appropriate level of detail (aggregate, intermediate, detailed).
- o Identify relevant activities.
- o Define relationships among activities (dependency, concurrency).
- o Forecast time durations.
- o Involve all relevant individuals in all of the above.

In many situations, program managers assume the responsibility for planning, scheduling, and controlling projects that consist of numerous separate jobs or tasks performed by a variety of departments, program offices, and individuals. Often, these programs are so complex and/or large that the program manager cannot possibly remember all the information pertaining to the plan, schedule, and progress of the program. In these situations the techniques of PERT and CPM have proven to be extremely valuable in assisting program managers in carrying out their program management responsibilities. Besides being one of the original scheduling techniques, PERT, which was developed during the Polaris submarine program in the late 1950's, was also the first risk analysis tool. The objectives of PERT are to manage schedule risk by establishing the shortest development schedule, to monitor project progress, and to fund or apply necessary resources for maintaining the schedule. Figure 5.8-1 represents a PERT network.

One of the most significant outputs of a network is the identification of the critical path. The critical path consists of those program activities which must be completed on schedule or the

Figure 5.8-1 Program Represented as a Network



overall program completion date will slip. Activities on the critical path are the "long poles in the tent." In addition, activities can be assigned unique identifier codes. One of the many options this permits is the capability to select those activities related to a specific WBS element which are on the critical path. Activities which are not on the critical path have slack time associated with them. This means that there is some amount of time that the activity's scheduled completion date can slip without impacting the overall program completion date.

5.8.2 Description of technique. The original networking technique was based on the Arrow Diagram Method (ADM) or "activity on arrow" method of representing the logical relationships between activities. ADM represents all predecessor and successor activities as finish to start relationships. Successor activities are not initiated until the predecessor is 100% complete. Since this form of relationship is not always true for predecessor/successor activities, other networking methodologies were developed to more accurately reflect the realities of predecessor/successor dependencies. Newer computer-based networking systems use the Precedence Diagramming Method (PDM), or "activity on node," to represent network logic. PDM allows greater flexibility than ADM in describing predecessor/successor relationships. With PDM, the following relationships can be described in addition to finish to start:

- o *Finish to Finish* - successor activity cannot finish until some user specified period of time after the predecessor has completed.

- o *Start to Start* - the successor activity cannot start until some user specified period of time after the start of the predecessor.

- *Start to Finish* - the predecessor activity cannot be completed until some specified period of time after the predecessor has started.

Newer network based risk models use PDM as well as conventional ADM. The description that follows is based on the traditional ADM networks because, to date, they are more popular as risk tools. PDM, however, is more popular as a scheduling tool.

To accurately reflect the realities of risk related issues, the PERT method of network analysis has been enhanced over the years. Logic has been added which increases the functionality of network analysis as a risk analysis tool. Because of the changes, some of the old terminology has been replaced. The lines are known as arcs instead of activities. Decision points at the initiation or completion of activities and milestones are referred to as "nodes." Nodes can be of three types:

(1) Source nodes - indicate the initiation of the program.

(2) Intermediate nodes - indicate milestones or the initiation and termination of arcs.

(3) Terminal nodes - represent the completion of the program or the failure to complete some segment of the program.

In a probabilistic network, there are two ways in which uncertainty manifests itself. First, activities may have uncertain outcomes in terms of time to complete, cost to complete, or achievement of some technical level of performance. Generally, technical performance is held as a fixed parameter while the other two vary. Second, the initiation of activities emanating from a node may be predictable only in a probabilistic way. For example, a test outcome (pass/fail) may determine whether the next activity is a progressive continuation of a plan or a corrective action. Since the test outcome cannot be predicted with certainty, it assumes a probabilistic nature. The network model represents this by showing at least two arcs emanating from the node representing test activity completion. The analyst can assign probability functions to the arcs to represent the relevant probabilities of completing within time or cost constraints, or of meeting performance levels.

An important aspect of network models that is needed to permit realistic simulation of programs is varied "node logic." Node logic refers to the rules which determine when, for example, a decision point is passed and when a subsequent activity initiates. The more advanced computer programs will allow use of both "AND" and "OR" logic, and "DETERMINISTIC" and "PROBABILISTIC" output node logic. The two types of input logic determine whether all ("AND" logic), only one (exclusive "OR" logic), or some ("OR" logic) of the possible arcs entering a node must be completed for the node to be actuated.

The two output logics determine whether all ("DETERMINISTIC" logic), or only one ("PROBABILISTIC" logic), arc are initiated upon completion of node actuation.

As previously mentioned, of fundamental importance for network development is the selection of the appropriate level of network detail. The consensus is that completion of a high aggregate level of detail should be accomplished before attempting to model the details of the program structure. Aggregate level networks will provide a more realistic determination of what the detail level networks will contain. Aggregate level networks, however, will also contain more inherent uncertainty than would be the case at a finer level of detail. As the program requirements and information become more readily available, the network models will evolve to a greater level of detail.

5.8.3 When applicable. Network analysis has universal application in program offices. Networks are formulated based on program activities, inter-relationships among activities, and constraints (time, money, manpower, technology). Because all programs have these characteristics, network analysis is universally applicable. The application of network analysis is made easier if network based program schedules already exist. If this is the case, the analyst can make the logic modifications required so that the network information can be readily input into a risk analysis software program. If a network does not already exist, one must be created. The time savings which can be incurred transforming an existing network, versus creating one, provides a strong argument in favor of network based program scheduling from the onset of a program.

5.8.4 Inputs and outputs. The input for the development of the network risk model consists of probability density functions (see Section 5.2 and Appendix F for discussion on some of the techniques available for quantifying expert judgment). Since input to the network model may initially be qualitative judgment which must be transformed into quantitative information, it is imperative that all individuals who play a relevant programmatic role provide input during the development process. The credibility of the resulting network is affected by the extent to which knowledgeable, relevant program personnel contribute to its development. Standard output from network risk models includes probability curves, barcharts comparing baseline and "risk free" schedules, cost histograms, Cumulative Density Functions (CDFs); and the mean, standard deviation of the sample, coefficient of variation, and mode for all specified decision points and activities. These result from executing a Monte Carlo simulation of the network. This is simply modeling the execution of the program many times. Most packages also produce a "criticality index" for each activity. This index shows how often each activity appeared on the critical path during the course of the simulation process. Cost curves and histograms can also be produced which may indicate the direction the project is taking. This information can be used to continually adjust labor, material, and time estimates.

5.8.5 Steps is applying the technique. The first step in the process of modeling a program is for the analyst/manager to manually develop a rough-cut network. In order to develop a realistic model of the program, it is crucial that the analyst identify all the relevant parameters such as nodes, arcs, logic relationships, and PDFs. As previously stated, all relevant program personnel should play a role in developing and validating the network.

Once the rough-cut network has been developed, the analyst can input the information into the computer for processing. There are many software packages currently available for network risk analysis. The whole spectrum from mainframe to microcomputer applications is covered by available software. Some of the packages currently available include PROSIM, VERT, VERTPC, RISNET, PROJECT/2, and OPERA.

Once the iterative process of developing the rough-cut network has been completed, the data is ready for input and processing by the computer. Using the process known as Monte Carlo simulation, the software determines the most likely course of events. Since one simulation conveys little useful information, the Monte Carlo simulation repeats the process, recalculating the critical path as many times as necessary (or as defined by the user) to account for all possible scenarios. Typically, 1,000 to 6,000 simulations are processed. The result of these simulations is a statistically calculated scenario that predicts the eventual course of the project with a confidence level as specified by the user.

5.8.6 Use of results. The output of the network risk analysis process is extremely useful to the program manager. The performance of network risk analysis generally provides an in-depth understanding of the sources and degree of risks. The results of the risk analysis process provide the information required to effectively execute the "risk handling" phase of risk management.

5.8.7 Resource requirements. Since most network risk assessments accomplished in the FAA are carried out by functional support offices, risk assessment dollar costs should be estimated from manpower requirements. A comprehensive networks analysis for a major program may require definition of between 200 and 1000 activities and require two to six man-months of GS-12 to GS-14 analyst effort for gathering information from subject experts for use in formulating PDFs and for building the network. Obtaining the information required to construct the network usually entails more time and rechecking than might initially seem necessary. This is because the program plan is usually under continual revision and definition, and the support personnel do not fully understand the relationships among the program activities. Although the difficulty and time required for network definition can pose a problem, the effort of constructing a consistent and acceptable network model forces the responsible participants to plan effectively and to understand how their own segment of the program fits into the whole. Program managers have indicated that this benefit alone can justify all the effort for accomplishment of a formal network risk assessment/analysis.

5.8.8 Reliability. The reliability of network risk analysis is a function of multiple factors. The development of a network which accurately reflects the activities and relationships among activities is crucial to the resulting network analysis. This is why it is imperative that all relevant program personnel provide input to the development and/or modification of the network. The definition of PDFs for the cost, schedule, and performance aspects of the program is also of fundamental importance. Since the Monte Carlo simulations which predict the course of the project are based on the respective PDFs, the accuracy of the PDFs in describing the cost, schedule, and performance parameters of the program is critical for a reliable analysis. The more reliable the network developed, the more reliable the analysis will be.

5.9 LIFE CYCLE COST ANALYSIS

5.9.1 General. A survey of program management offices indicated that directed funding cuts most often were viewed as the source of risk having the major impact on program execution. In order to control the adverse consequences of such a risk, a program manager needs to be able to quickly determine the potential cost implications of new information, such as funding constraints, pertinent to the program. Other information affecting program costs include new knowledge about a wide range of things, such as test failures resulting in schedule slips or directed production rate reductions. The program manager also needs to have quick access to the potential cost implication of some of the choices that must be made as the program progresses. Many programs meet such needs with a computerized Life Cycle Cost (LCC) model. These models are sometimes called quick reaction cost models or quick reaction models. Such models can be useful for cost estimating, tradeoff analysis, production rate and quantity analysis, warranty analysis, sensitivity analysis, and logistic support studies. Simpler models, such as the Quick Cost model developed by DSMC, are focused specifically on the cost implication of changes in yearly production quantities.

5.9.2 Description of technique. The Life Cycle Cost technique consists of a series of equations which compute program costs based on product and program information. The exact nature of such information will be addressed in Section 5.9.4. It will vary from model to model, and may vary significantly from program to program, depending on the nature of the program and its status. An important aspect of LCC models is that given some informed inputs, the model can be run quickly and not only provide a new total LCC cost estimate, but also can give some insight into where the costs are likely to change. The model equations are usually developed based on logic and experience on similar past programs. The cost elements of LCC models vary significantly. Where applicable, they usually include development, production, and the full spectrum of extended operating and support costs.

5.9.3 When applicable. Use of a LCC model is applicable whenever a manager needs a quick estimate of the cost implications of a past or pending event. The timely development of useful cost estimates is totally dependent upon having a completed and tested LCC model available for immediate use. Such a model is very applicable to situations where budget cuts are proposed by higher authority and the PMO has only a short time to describe the impact of such cuts. Program managers can get into trouble trying to buy half the quantity for half the cost, or the same quantity over a longer period, for the same cost.

5.9.4. Inputs and outputs

Inputs - Most LCC cost models have extensive inputs that vary from model to model. Timely use of these models dictates that input values be continually maintained so only those that would change because of recent or pending actions need to be obtained to carry out the desired cost analysis. This is especially important when using detailed LCC models which aggregate costs based on the characteristics of many individual subsystems and line replacement units. Important input values common to many life cycle cost models include:

- o Production quantity by year
- o Development test quantities
- o Cost quantity curve slopes
- o Support equipment requirements
- o Number of bases to which equipment will be deployed
- o Spares requirements
- o Tooling costs and other non-recurring production costs
- o Deployment life of system
- o Planned utilization rate (i.e., operating hours per year)
- o Failure rates, sometimes by subsystem or even component.

Outputs - As with model inputs, the nature and format of the outputs vary widely among LCC cost models. One output option should include an overall summary of total life cycle costs broken out only by appropriation type, (i.e., development, production and operation). Other useful output options include breakouts of the total life cycle cost by:

- o Year
- o Cost element
- o Equipment component
- o Combinations of the above.

Output values may be in fixed and specified base year dollar values, or if inflation rates were provided in the input, as dollar values inflated to the year in which they must be appropriated.

5.9.5 Major steps in applying the technique. The first major step in using a LCC model is to develop a model tailored to the nature of the program and anticipated cost information needs. this is a key step because, without it, generation of timely LCC estimates will not be possible. Developing such a model and gathering the required input values will usually require a significant resource commitment. This effort can often be significantly reduced by tailoring an existing LCC model already in use for a similar system.

The second major step is using the LCC model to address a specific issue. This could require a data collection effort, but it should be significantly less than the initial effort to develop a model tailored to a specific PMO. If a model is already available and programmed on a computer, gathering the input data required to run the model is almost always the largest part of the effort required to prepare an LCC estimate.

The last major step is to review the model output and ensure that the results are reasonable and address the questions at issue. Any single LCC analysis might involve computation of several to many estimates. The LCC model is only a very crude abstraction of the real world. Decision makers, therefore, often demand and will always appreciate logical arguments that tend to substantiate the numerical results provided by the model. It is often prudent to use the model to do sensitivity analysis using a range of input values around the primary input values to see how the changes affect the model computed LCC estimates.

5.9.6 Use of results. LCC analysis results can be used to assess costs and, thereby, cost risks associated with many decision issues. LCC models can be used to develop or carry out:

- o LCC estimates
- o Production rate and quantity analyses

- Design trade-off analyses
- Cost driver sensitivity analyses
- Resource projections (e.g., manpower, support equipment)
- Repair level analyses
- Warranty analyses
- Spares provisioning and optimization
- Reliability growth analyses
- Operational availability analyses.

5.9.7 Resource requirements. The development, programming, and testing of a PMO-tailored LCC model could require 6 to 12 man-months of GS-12 to GS-13 level analyst effort. This time can be significantly reduced if an existing LCC model can be found and tailored to the PMO. Several general purpose models are available

and were designed to be tailored to specific PMO needs. The Cost Analysis Strategy Assessment (CASA) models were developed for and distributed by the Defense Systems Management College for this purpose. The CASA models are screen-oriented, user-friendly programs which can be operated on microcomputers. Use of these programs can be quickly mastered by GS-12 level analysts, using the users guide provided by DSMC with copies of the program. The most significant task associated with using such models is obtaining complete and valid input data. Input data requirements may include key values such as the first unit production costs. The CASA is only one of several LCC models available. Program management office personnel should make every effort to find the LCC model most applicable to their program before initiating efforts to modify an existing model or to develop a new model from scratch.

5.9.8 Reliability. Use of LCC models for analysis is relatively common in the FAA and is widely accepted as a quantitative basis for decision-making. It may enhance the credibility of a PMO analysis in the view of higher levels of authority, if an LCC model is selected that is closely related to one that has already gained acceptance. Inquiries should be made to see if such a model is available. All models have the limitation that the input data values must reflect the significant and valid differences among alternatives, if the model is to produce valid and useful cost differences among alternatives.

5.10 COST RISK/WBS SIMULATION MODEL

5.10.1 General. This technique aggregates cost risks for each of several WBS elements of a program into the total program cost risk. The total program cost risk is usually expressed as a cumulative probability distribution of total program cost. Such distribution information can be used to reflect program risk by computing the probability the program can be completed for a specific dollar value or less, and what level of funding would be required to have a given probability of completing the program within the available funds. A micro or other computer is required to use this technique, because the analysis requires many repeated computations during simulation operations. Similar cost risk analysis can be performed as part of the analysis of networks by such models as VERT; however, network models usually require significantly more input data than pure cost risk/WBS simulation models.

5.10.2 Description of technique. This method uses the Monte Carlo simulation analysis method. Variations of the technique use different probability distributions to describe the cost risk associated with each WBS cost element. Uniform, Triangular, Beta, and other probability distributions have been used for this purpose. Use of the Uniform and Triangular distributions made the computation easier. Use of the Beta distributions, however, allows the user more freedom in describing WBS cost element uncertainty. Various techniques of this general type differ on how much data they require

for each WBS cost element, and the format used to present analysis results and assumptions with respect to the interdependence among WBS element costs. The technique uses a random number generator to simulate the uncertainty for individual WBS elements. Once costs have been simulated for each WBS element, they are aggregated to get a total program cost estimate. This process is repeated many times. Each time a new set of WBS element costs are developed is called an "experiment." The results of many such experiments provide a frequency distribution of total costs, reflecting the aggregate of the cost risks associated with all the individual WBS elements.

5.10.3 When applicable. Use of this technique is applicable when there is a need for knowing the probability the program can be successfully completed at various levels of funding. It is also applicable when there is a need to know what level of funds are needed to achieve a specified probability of completing the program at that level of funding or less. For this technique to be applicable, it is also necessary to be able to obtain sound estimates of the cost uncertainty associated with each WBS element in the program. When a cost estimate broken out by WBS is already available, it is a relatively quick analysis procedure to use.

5.10.4 Inputs and outputs. Inputs and outputs vary among models implementing this type of analysis technique. As an example of input and output information, a simplified version of the Air

Force Systems Command (AFSC) Risk Model will be used. The AFSC Risk Model is probably the most widely used model of this type because its use has been directed as part of all major AFSC cost estimates. One unique aspect of the ADSC Risk Model is that it requires four estimates of cost uncertainty for each WBS element. Since the model essentially uses only the one of these estimates having the highest risk, the discussions of inputs will just address a single set of uncertainty descriptive data for each WBS element.

Inputs - For each model run, five elements of data are required once and five elements of data are required for each and every WBS cost element constituting part of the total program cost estimate. They are:

- o For each model run
  - System name
  - Monte Carlo sample size (default value is 2500)
  - Confidence level computation desired (default value is 90 percent)
  - Dollar units used for inputs
  - Date of run

- o For each WBS cost element
  - WBS element name
  - Point cost estimate (most likely)
  - Low end of cost range value (percentile defined by model)
  - High end of cost range value (percentile defined by model)
  - Level of WBS element cost variance value (judgment value of low, medium low, medium high, or high)

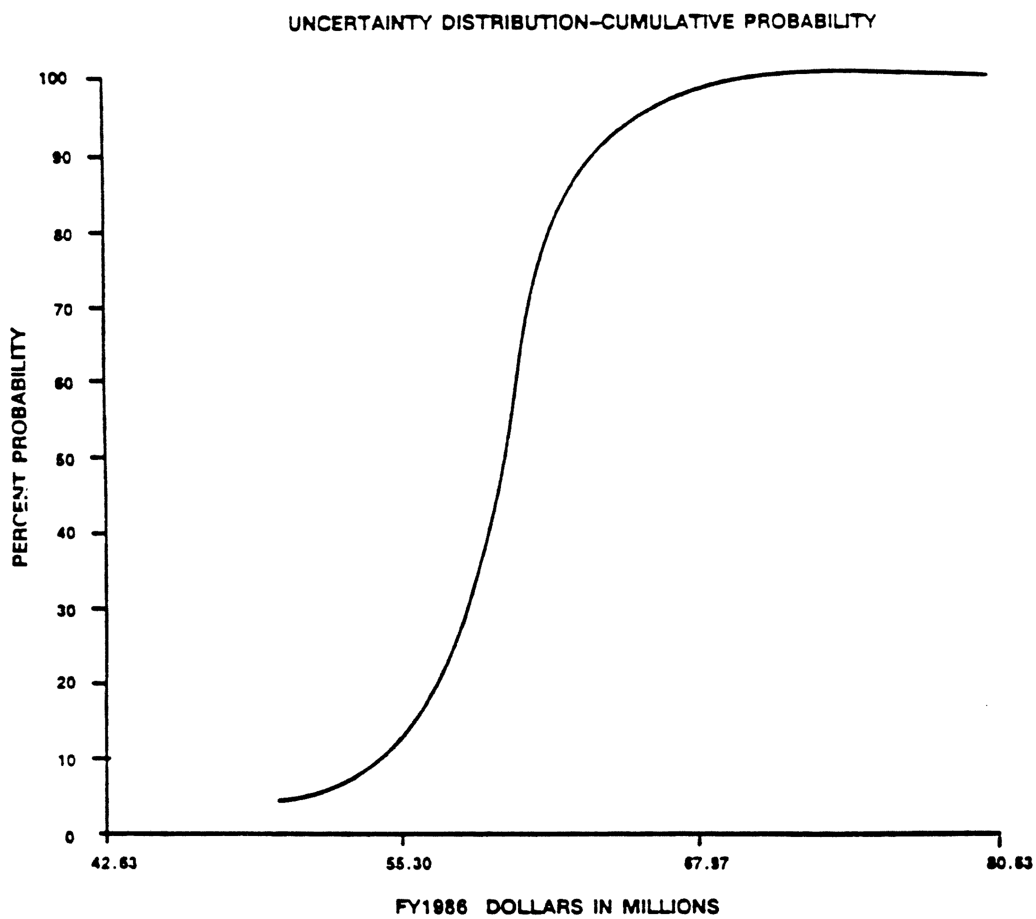
Outputs - The basic WBS simulation model output is illustrated by Table 5.10-1. It shows into which of 60 sequentially increasing cost ranges each of the 2500 simulated total cost estimates fall. As an example, eight of the 2500 simulation experiments produced a total cost estimate between 47.7 and 48.3 million dollars and, thereby, fell in the tenth interval. Such data can be used to develop total cost probability and cumulative probability curves. Figure 5.10-1 is an example of such a cumulative probability curve based on the results in Table 5.10-1. The same data can also be used to provide

Table 5.10-1 Model Output

(EACH INTERVAL EQUALS .63 MILLIONS)

-INTERVAL	RANGE			FREQUENCY	PROBABILITY	CUM PROB
1	42.0000	-	42.6333	0	.000	.000
2	42.6333	-	43.2667	0	.000	.000
3	43.2667	-	43.9000	0	.000	.000
4	43.9000	-	44.5333	0	.000	.000
5	44.5333	-	45.1667	0	.000	.000
6	45.1667	-	45.8000	0	.000	.000
7	45.8000	-	46.4333	0	.000	.000
8	46.4333	-	47.0667	0	.000	.000
9	47.0667	-	47.7000	1	.000	.000
10	47.7000	-	48.3334	8	.003	.003
11	48.3334	-	48.9667	13	.005	.008
12	48.9667	-	49.6000	9	.004	.012
13	49.6000	-	50.2334	11	.004	.016
14	50.2334	-	50.8667	19	.008	.024
15	50.8667	-	51.5000	27	.011	.035
16	51.5000	-	52.1334	45	.018	.053
17	52.1334	-	52.7667	46	.018	.071
18	52.7667	-	53.4000	48	.019	.090
19	53.4000	-	54.0334	72	.029	.119
20	54.0334	-	54.6667	57	.023	.142
21	54.6667	-	55.3000	63	.025	.167
22	55.3000	-	55.9334	89	036	.203
23	55.9334	-	56.5667	101	.040	.243
24	56.5667	-	57.2000	92	.037	.280
25	57.2000	-	57.8334	112	.045	.325
26	57.8334	-	58.4667	133	.053	.378
27	58.4667	-	59.1000	130	.052	.430
28	59.1000	-	59.7334	119	.048	.478
29	59.7334	-	60.3667	135	.054	.532
30	60.3667	-	61.0001	120	.048	.580
31	61.0001	-	61.6334	134	.054	.634
32	61.6334	-	62.2667	143	.057	.691
33	62.2667	-	62.9001	99	.040	.731
34	62.9001	-	63.5334	104	.042	.773
35	63.5334	-	64.1667	106	.042	.815
36	64.1667	-	64.8001	85	.034	.849
37	64.8001	-	65.4334	60	.024	.873
38	65.4334	-	66.0667	60	.024	.897
39	66.0667	-	66.7001	41	.016	.913
40	66.7001	-	67.3334	52	.021	.934
41	67.3334	-	67.9667	50	.020	.954
42	67.9667	-	68.6000	52	.021	.975
43	68.6000	-	69.2334	22	.009	.984
44	69.2334	-	69.8667	14	.006	.990
45	69.8667	-	70.5000	2	.001	.991
46	70.5000	-	71.1334	10	.004	.995
47	71.1334	-	71.7667	7	.003	.998
48	71.7667	-	72.4000	6	.002	1.000
49	72.4000	-	73.0334	1	.000	1.000
50	73.0334	-	73.6667	1	.000	1.000
51	73.6667	-	74.3000	0	.000	1.000
52	74.3000	-	74.9334	0	.000	1.000
53	74.9334	-	75.5667	0	.000	1.000
54	75.5667	-	76.2000	1	.000	1.000
55	76.2000	-	76.8334	0	.000	1.000
56	76.8334	-	77.4667	0	.000	1.000
57	77.4667	-	78.1000	0	.000	1.000
58	78.1000	-	78.7333	0	.000	1.000
59	78.7333	-	79.3667	0	.000	1.000
60	79.3667	-	80.0000	0	.000	1.000

Figure 5.10-1 Model Output



output information with respect to the confidence level that a program can be completed for a specified level of funding or the funding required to achieve a specific level of confidence that the program will cost that value or less.

5.10.5 Major steps in applying the technique. The first step in applying this type of technique is to obtain and become familiar with one of several available computer programs implementing it, and the associated model user guidance. It will seldom be practical or desirable to develop such a computer program from scratch. The second major step is to obtain the input data required by the specific model obtained in Step 1. This step is greatly facilitated if a total program cost estimate is already available, broken out by WBS element. If such an estimate is available, the required WBS cost element uncertainty input data can generally be obtained by interviewing PMO personnel. If possible, historical cost data should be reviewed to see how widely similar WBS cost values vary on other programs. The third step is to load the input data into the model and make one or more model runs as necessary. This is generally far less time consuming than gathering the input data. The last step is to examine the model output results to ensure they appear reasonable and provide the type of information needed to show how WBS element risks affect total program cost risk.

5.10.6 Use of results. The primary use of WBS simulation model results is to show how WBS element risks may cause total program costs to vary from the point estimate used for budgets and other purposes. It can also be used to compare estimated costs for several programs at a specified confidence level, such as 90 percent. Higher headquarters may ask to see such information as part of the normal review process.

5.10.7 Resource requirements. The primary resource requirement is a copy of a computer program implementing this method and the associated user guidance. Air Force experience has shown that GS-9 and above cost analysts can quickly learn to run such a model, if supported by PMO specialists in providing WBS cost element uncertainty range and level judgments. A microcomputer is also required. Th AFSC risk model runs on a Zenith 100 computer. Other similar model run on IBM PCs.

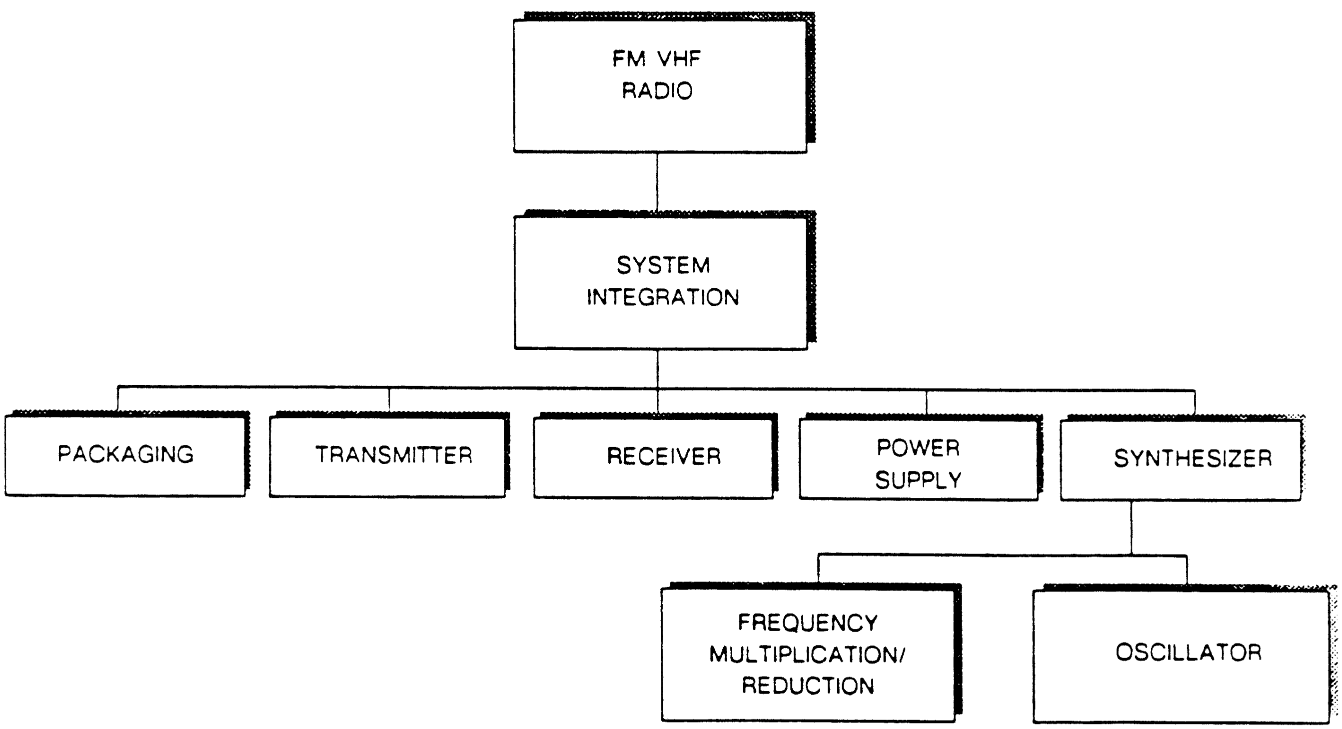
5.10.8 Reliability. The mathematics and logic of the WBS simulation/cost risk technique are generally sound. An exception is that these models generally do not fully address the interactions between WBS elements. They usually assume either total dependence or total independence among WBS elements. The true situation will probably vary from program to program, and will almost always be somewhere between total independence and total interdependence. The greatest limitation of this method is the difficulty in obtaining sound and supportable input values.

5.11 RISK FACTORS

5.11.1 General. This method is often quite simple to apply except for the difficulty in obtaining sound and dependable input values to describe the risk associated with each WBS element. Often the input values are quick judgments made by PMO personnel. The method does not include procedures for systematic and scientific development of the needed input data The pri ary use of the method is to estimate the total added progr costs t at might be expected due to risks associated with the var s program WBS elements.

5.11.2 Description of technique. The basic concept of the Risk Factor method is to determine factors, or multipliers, with which to increase individual baseline WBS element cost estimates to cover additional costs resulting from risks. The objective of using this method is to determine a reasonable budget, above that resulting from a baseline cost estimate, to cover anticipated risk associated cost growth. The method uses a WBS or cost breakdown structure based on a technical breakdown like that shown in Figure 5.11-1. The baseline cost estimate must have been developed for each cost element. Applying whatever considerations are appropriate, a risk factor is established for each cost element. This factor will generally be a value between 1.0 and 2.0, with 1.0 indicating no risk and 2.0 indicating so much risk that expected costs would be twice the baseline cost estimate values. Every baseline WBS cost estimate is then multiplied by its risk factor to obtain the new WBS element cost estimates. These new estimates are summed to get a budget value, which provides a level of funding which will account for technical or other risk.

Figure 5.11-1 Cost Breakdown Structure



The identification of sound WBS element risk factors is the key feature of this method and may be difficult. There is little documented experience upon which analysts can draw in order to substantiate such factors. Since these factors have a significant impact on the analysis results, it is important that the inputs be obtained from highly experienced technical experts. In other words, the apparent simplicity of the method has not relaxed the requirement that the most experienced PMO personnel take key roles in the analysis. Once a baseline cost estimate has been prepared using cost estimating methods, an analyst should be able to prepare a new cost estimate using risk factors in a relatively short time. The length of time will depend on the difficulty an analyst has in obtaining the assistance of technical experts, and on how detailed a WBS or cost breakdown is involved.

5.11.3 When applicable. The technique is more applicable early in the life of a program when information is not available to apply some of the more sophisticated risk analysis techniques. This technique is only applicable when a point cost estimate, broken out by WBS element, is available. The method's simplicity makes it applicable to even small, low cost programs.

5.11.4 Inputs and outputs. One primary, and generally available, input of a risk factor assessment is a baseline cost estimate broken out by WBS element. The second primary input is a set of risk factors for each WBS cost element. These factors will usually be subjective judgments of experienced personnel who know the program, its current status, and potential problem areas. The use of check or watch lists and the number of items in the list that apply to each WBS element is one way of helping make a judgment of the level of risk associated with each element. The output of a risk factor application is a budget or cost estimate increased over the baseline budget (or estimate) by an amount required to cover risk induced costs.

5.11.5 Major steps in applying the technique. The major steps in applying the technique are:

(1) Obtain a program cost estimate broken out by WBS element. Such estimates should be available and their preparation is not considered to be part of applying this method.

(2) For each WBS element, obtain an estimate for the percent of additional costs that should be added to accommodate additional work resulting from risks. The opinions of knowledgeable technical and experienced program management should be sought and used. Reviewing the lessons learned for similar systems could also provide insight into how much risk might be involved. If similar things have been done before, and by the same people assigned to the current program, risks should be lower. It must be remembered that past programs were also risky and, therefore, parametric cost estimates based thereon also include some costs to cover risk.

(3) Recalculate the total program costs by summing all the WBS element costs, each of which has been adjusted by the associated factor percentage increase to accommodate the risks associated with it.

5.11.6 Use of results. According to the survey of PMO risk analysis applications, several PMOs found the results of Risk Factors analysis of some significant use for budget preparation, program status reporting, program planning and milestone briefings. This method has also been used to support U.S. Army cost risk procedures.

5.11.7 Resource requirements. Resource requirements for this method can be quite variable. Frequently, the same cost estimator responsible for preparing the baseline cost estimate can also provide the additional risk factor results in a few hours, if he/she is provided the WBS element factors by appropriate experts in a timely manner. Application of the method can become more involved as more technical and other experts are used to derive the individual WBS element risk factors.

5.11.8 Reliability. The reliability of this technique can vary widely both in fact and in the judgment of those reviewing the results. Since use of the technique generally requires judgments based on limited information, the knowledge and skill of those making the judgments will greatly affect the reliability of the results. A quick analysis, where the risk level factor judgments for all WBS elements are made by a single cost analyst without inputs from technical and other experts, would very likely produce relatively low reliability results. The reliability of this method is increased by providing documented justification for all WBS element factor values used.

5.12 PERFORMANCE TRACKING

5.12.1 General. Much has been written about technical risk. The GAO report on technical risk in April 1986, spent a great deal of space discussing the importance of managing the technical aspects of a program. Measuring technical risk on any effort that involves furthering the state-of-the-art is a very difficult task, which in and of itself, can involve a great amount of risk. There are some concrete measurements than can be useful in measuring technical advancement progress against preset goals of programs. Many of these are described in a publication entitled "Technical Risk Assessment: Staying Ahead of Real-Time Technical Problems, Visibility and Forecasts" (currently in draft form). This is a Navy document released in March 1986[1]. Within the document are several recommended measures for evaluating technical progress.

5.12.2 Description of technique. The technique advocates the use of a Technical Risk Assessment Report, which is updated monthly. The report is based on working level data, but is intended to provide an overview of current trends and status. The technique uses a set of standard technical indicators which have been proven to be effective measures of technical performance. In addition to the standard measures, program unique technical indicators are also developed. Each of the measures has clearly defined performance projections and pre-set alert criteria. The standard indicators are shown in Figure 5.12-1.

5.12.3 When applicable. The performance tracking technique is most useful when there are specific criteria established that are objective and quantifiable. It can best be utilized for the management of near term requirements. The approach can be used with minor modifications on any type of program, and could be used in conjunction with more elaborate probabilistic risk models that can examine the corresponding cost and schedule impacts of current technical performance.

5.12.4 Inputs and outputs. The technique requires that performance be tracked on a monthly basis for each technical indicator selected. This requires full cooperation with the contractor and its active participation in managing risk (a good benefit). The output can be in the form of a risk management report or a briefing. The contents should contain an analysis of each of the indicator's current performance and longer term trend.

5.12.5 Major steps in applying the techniques. One of the first steps in adapting the technical risk assessment method to track risk performance is to select the standard indicators that can be applied to the development program. Many of the standard indicators (Figure 5.12-1) can be used on development programs, and the utility of certain indicators will vary as the program progresses. In the case of an airborne system, weight and size are always significant. The selection of indicators should include ones for the entire program and selected ones for the subsystems. The unusual aspects of a developmental program frequently require the use of special technical indicators. In the case of space systems, certain indicators are appropriate such as the production of gasses from the material in the product when exposed to a space environment. Figure 5.12-2 shows some potential special indicators.

Each indicator, whether standard or special, must have ground rules established for data collection and assessment. This can be in the form of a dictionary which describes the object of the indicator, why it was chosen, the use of the indicator, and what is to be done when a signal is generated that indicates a problem is developing. It should be in sufficient detail to inform the system operator of the meaning of the indicator and the relationship of the measurement to risk.

It is advisable to predict the trends that might be expected during the life of the indicator. Expected values may take many different forms or curve functions, but should have a traceability to the program goals, either cost, schedule, performance, or various

Figure 5.12-1 Standard Indicators

AREA OF RISK	TECHNICAL RISK INDICATOR (TYPICAL UNIT OF MEASURE)	APPLIES TO: SYSTEM	SUBSYSTEM: SUBSYSTEM A	SUBSYSTEM B	SUBSYSTEM C	SUBSYSTEM D	SUBSYSTEM E	SOURCE: STATEMENT OF WORK	CONTRACT SPECS	CONTRACTOR PLANS	PRIOR EXPERIENCE
DESIGN	WEIGHT (POUNDS)	X	X	X	X	X	X		X		
	SIZE	X	X	X	X	X	X		X		
	CENTER OF GRAVITY (INCHES FROM REF. POINT)	X	X	X	X	X	X		X		
	THROUGHPUT (CLUSTERS PER MINOR CYCLE)	X							X		
	MEMORY UTILIZATION (PERCENTAGE OF CAPACITY)	X							X	X	
	DESIGN TO COST (DOLLARS)	X	X	X	X	X	X	X			
	DESIGN MATURITY (NUMBER OF DESIGN DEFICIENCIES)	X	X	X	X	X	X	X		X	X
	FAILURE ACTIVITY (NUMBER OF FAILURE REPORTS SUBMITTED)	X	X	X	X	X	X	X		X	X
	ENGINEERING CHANGES (NUMBER OF ECOs)	X	X	X	X	X				X	X
	DRAWING RELEASES (NUMBER OF DRAWINGS)	X	X	X	X	X				X	X
	ENGINEERING MAN-HOURS (MAN-HOURS)	X	X	X	X	X				X	X
TEST	CRITICAL TEST NETWORK (SCHEDULED DATES FOR CRITICAL TEST EVENTS)	X	X	X	X	X				X	X
	RELIABILITY GROWTH (MEAN TIME BETWEEN FAILURES)	X	X	X	X	X		X	X	X	X
PRODUCTION	TRANSITION PLAN (SCHEDULED DATES FOR CRITICAL PRODUCTION EVENTS)	X	X	X	X	X				X	X
	DELIQUENT REQUISITIONS (NUMBER OF DELINQUENCIES)	X	X	X	X	X				X	X
	INCOMING MATERIAL YIELDS (PERCENTAGE OF ACCEPTABLE MATERIAL)	X	X	X	X	X				X	X
	MANUFACTURING YIELDS (PERCENTAGE YIELD)	X	X	X	X	X				X	X
	UNIT PRODUCTION COST (DOLLARS)	X	X	X	X	X		X			
	UNIT LABOR & MATERIAL REQUIREMENTS (MAN-HOURS UNIT & MAT'L COST UNIT)	X	X	X	X	X				X	
COST	COST AND SCHEDULE PERFORMANCE INDEX (RATIO OF BUDGETED AND ACTUAL COSTS)	X	X	X	X	X		X			
	ESTIMATE AT COMPLETION (DOLLARS)	X	X	X	X	X				X	
	MANAGEMENT RESERVE FUNDS (PERCENTAGE REMAINING)	X								X	
MGMT	SPECIFICATION VERIFICATION (NUMBER OF SPECIFICATION ITEMS)	X	X	X	X	X			X		
	MAJOR PROGRAM RISK (RANKED LISTING)	X	X	X	X	X					X

Figure 5.12-2 Sample Special Indicators

INDICATORS DERIVED FROM SPECIFICATION REQUIREMENTS	INDICATORS DERIVED FROM PROGRAM REQUIREMENTS
PERFORMANCE CHARACTERISTICS o Speed, Range, Capacity, Accuracy	SCHEDULE o Feasibility, Probability of Timely Accomplishment
PHYSICAL CHARACTERISTICS o Center of Buoyancy, Length	RESOURCES o Adequacy, Distribution
EFFECTIVENESS CHARACTERISTICS o Reliability, Safety, Logistics Support	TEST PLAN o Sufficiency of Planned Testing
ENVIRONMENTAL CONDITIONS o Vibration, Temperature, Shock	PROCUREMENT FACTORS o Availability of Multiple Sources
DESIGN AND CONSTRUCTION o Technology, Packaging, Materials	

combinations. Evaluation criteria must be set so as to flag a situation that can signal a problem. Color coding such as red, yellow, or green for high, medium, or low risk can be used as well as percentage bands for the same type of message. These bands may vary at time progresses; that is, getting tighter as completion is nearing, or getting more tolerant as time passes to indicate a risk that is disappearing. In any case, the program office, contractor, and subsystem contractor(s) all must agree to and understand the tolerance bands and their significance in order to facilitate rapid corrective action.

All the above would be useless unless a formal, contractually required reporting system is used. This could be in different form, according to the type of the program and the style of the manager. It may be produced in vugraphs in a manner immediately usable by the Government manager for required higher level periodic briefings or in a raw form as numerical data points. In any case, it must be in a form immediately applicable by both the contractor and the program manager to making decisions affecting the program. As in any system that requires the coordinated efforts of contractors and Government technical and management personnel, it is necessary to place someone in charge of ensuring that the job is being done accurately and in a timely fashion, and that the proper decision-makers are informed of the risk situations.

In summary, the major steps in applying risk management techniques are:

(1) Applying the standard indicators

(2) Selecting special indicators

(3) Establishing data definitions

(4) Projecting expected trends

(5) Setting the evaluation criteria

(6) Planning the reporting system

(7) Assigning responsibilities.

5.12.6 Use of results. The technical risk assessment reports furnish the information needed to start any action that might be required to correct potential problems. Each indicator should be examined separately and then examined as related groups of indicators. In using the results, the factors of cost, schedule, and technical risks must be examined simultaneously.

5.12.7 Resource requirements. This technique requires people with sufficient knowledge and skills in highly specialized technical areas. The data received emanates from many functional groups, including fabrication, assembly, engineering, and quality control, and must be analyzed by people who have these skills and can make technical analytical assessments of the reports. This does not mean that each functional risk assessment area requires a full time person. While system start-up costs vary, it should not require more than 1-2 man-months of effort. Typically, the sustaining costs are estimated to be a one person effort for a fairly large program.

5.12.8 Reliability. In order to have a reliable technical risk assessment, it is necessary that all major participants understand the importance of the assessment and be actively involved in establishing and implementing the system. Each member of the team should be involved in the initial assessment of the program's technical risk and help in the selection of the indicators used in tracking the risk. These are the same people who should be providing the updates for each reporting period. The early surfacing of potential problems anticipates the problem prior to failure and, with proper management action, failure may be precluded or at least tempered.

5.12.9 Performance Tracking - supplemental information. Performance tracking is not new. It has existed in one form or another for many years, but recently has gained in popularity and use. There are many variations on the theme presented in the above discussion. Since control is one of the most critical elements in risk management, and performance tracking is one of the most

effective control techniques, another variation of the method is presented below.

Fully integrated performance measurement - is a capability being developed to integrate technical performance, schedule performance, and cost performance. It is also aimed at providing Earned Value performance measurement capability to Government program offices that are not getting formal contractor performance data. The major steps are as follows.

(1) Technical Performance

- From program direction, plans, and specifications, identify specific technical parameters and their value for performance, producibility, quality assurance, reliability, maintainability, and support. A few examples are shown in Figure 5.12-3.

- Relate each of these technical parameters to specific WBS elements whenever practical. Many of them will only relate to the total system level, but many will come from the Spec Tree which should match the WBS.

- Define specific methods for calculating, measuring, or observing the value of each technical parameter.

- Assign a specific individual or organization the responsibility for managing the technical parameter and the progress toward achieving the goal value.

(2) Schedule Performance

- Identify (or create) specific schedule events at which calculation or observation is to be made.

- Determine values or conditions that should be achieved by each milestone. Set a tolerance or "alarm" value to represent a threshold for corrective action.

- Identify (or create) a specific schedule event at which the goal is to be achieved.

- Develop a plot of the technical performance parameter value against time to give a visual portrayal of the relationship between technical performance and schedule.

Figure 5.12-3 Fully Integrated Performance Measurement
Typical Technical Parameters

PERFORMANCE	PRODUCIBILITY	QUALITY ASSURANCE
- Speed (KTS) - Weight (Lbs) - Range (NM) - Power (KW) - Turn Rate (Deg/Sec) - Takeoff Distance (Ft) - Climb Rate (Ft/Sec) - Accuracy (Ft) - Radar Cross Section (Sq Ft)	- Capital ($) - Manpower (People Count) - Facilities (Sq Ft) - Material ($) - Equipment (Machinery Req'd) - Schedule (Time) - Risk (0-1.0)	- Scrap, Rework & Repair (% of Labor) - Yield (% of 1st Time (Inspection Successes) - Supplier Rating (%) - Quality Costs ($) - Customer Satisfaction (0-10) - Software (LOC in Violation per 1000 LOC)
RELIABILITY	**MAINTAINABILITY**	**SUPPORTIBILITY**
- MTBF (Hrs/Days) - MTTR (Hrs/Day) - LRU vs SRU (%) - Probability of Component/ Assy. Failure (0 - 1.0) - Life Cycle Analysis ($) - Design to Cost ($)	- Standardization (%) - Modularity (%) - Update Ability (0 - 1.0) - Special Equipment ($) - STE ($) - Frequency (Time) - Costs ($)	- Parts Inventory ($) - Costs ($) - Resources (Manpower, Equipment, Facilities) - Modularity (%) - Operational Avaliability (%) - MTBF (Hrs/Days) - MTTR (Hrs/Days)

(3) Cost Performance

- o Assign budgets to each technical performance parameter. These budgets may be real and add up to contractual values or fictious units just to determine relative weights. There are many different ways to assign these budgets. The only requirement is rationality, traceability, and consistency.

- o Distribute the assigned budgets to each of the measurement milestones based on engineering judgment of the percent of the total value associated with each milestone.

- o Use conventional earned value techniques to measure accomplishment (e.g. 50/50 milestones).

- o Apply the schedule performance index to appropriate activities in the resource loaded network to determine the cost impact of the technical and schedule performance.

5.13 OTHER COMMON TECHNIQUES

5.13.1 Common Performance Reports (CPR) analysis. CPRs have become useful in uncovering areas where technical problems are causing variances. In this report, the contractor explains cost and schedule variances by means of a narrative detailing the specific problem that has caused the variance. Many of the variances reported can signal risk situations as they are developing, such as late vendor or subcontractor deliveries. The continuation of these types of schedule slips can put an entire program schedule at risk. Normally, Government program managers are limited in what they can do to alleviate these situations, except in cases where Government Furnished Properties (GFP) are causing the delays. The GFP shortage situation can sometimes be alleviated by high level coordination with the supplying Government agency.

Cost variances can also be risk involved, as large cost growth can jeopardize a program to the point of causing cancellation. It is naive not to consider cost growth as a significant risk item. The CPR is designed to display cost growth as a variance and then discuss the variance in terms of cause, impact, and any corrective action that might be taken to alleviate the situation. If the program is receiving the CPR, it should be used for risk assessment and analysis by the program manager. A discussion of variances can contain data that permits the determination of items that may be presenting new and previously undiscovered risks. These risks should then be investigated to ascertain their effects on the program.

5.13.2 Independent technical assessment.

General - An independent technical assessment requires people other than those under control of the PMO and, therefore, will always require approval by some higher level of authority. The timing of such reviews is critical. If problems are found, there must be time to correct them before any critical milestone reviews. This technique has been used by a multi-service program and is cited as substantially reducing program risk, especially that which was associated with tri-service involvement.

Description of technique - This technique involves a team of experts from outside the PMO reviewing a number of specified aspects of the program. The team usually consists of very senior personnel who can make timely evaluations of PMO activities and progress based on their extensive experience. Such a team can vary in size, depending on the size of the program and how many issues the team has been chartered to review. The entire process is usually limited to four to eight weeks of near full time effort. The final product is almost always a briefing to the level of authority authorizing the review and sometimes a written final report.

When applicable - An acceptable time to use the technique is in support of design reviews. It can also be used to quiet or end perceptions of a troubled program. A good time for an independent technical assessment is when a program is, or is perceived to be, in trouble and critics have become vocal. If the trouble is real, this technique will give the PMO added credibility and quiet critics.

When possible, such reviews should be scheduled to cause minimum disruption of milestone activities. An independent technical assessment is usually more appropriate during system development than during production.

Inputs and outputs - The inputs will vary widely depending on the issues shown to be addressed and the expertise of the team members. Team members will obtain the information they need through briefings by PMO personnel, review of PMO documents, interviews, and visits to contractors' facilities. The expertise and experience team members bring with them to the team are an important input. The most common output is a briefing to the manager authorizing the review and to others, as appropriate. The briefing must address each of several criteria or issues defined at the onset of the review. It should also include recommendations for follow-on action.

Major steps in applying the technique - The following steps are common to most independent technical assessments:

- Direction by a higher level of authority with control of or access to the required expert resources, to conduct the review
- Specification of the issues to be addressed
- Formation of the review team
- Gathering the required information about PMO objectives, problems, status, resources, and activities
- Analyzing the information gathered
- Presenting the results to the authority who requested the review and to others as appropriate.

Uses of results - Independent technical assessments are useful for design, acquisition strategy, planning, and implementation coordination. When the review results are favorable, there is instant program risk reduction with associated benefits in meeting pending milestone reviews.

Resources required - Resources of two types are required to carry out an independent technical assessment. First, a team of up to 10 experts is needed to form the review team. The people required must be experienced and certainly would include some or all at the GS-15 level or above. These people would probably have to commit two to four weeks of effort to the team over a period of four to eight weeks. In addition to team resource requirements, the PMO has to provide a number of informational briefings and interviews to quickly provide the review team with the required information. Where members of the review team are visiting from out of town, the PMO may be required to perform substantial protocol and administrative tasks. The PMO usually pays all travel costs for team members.

Reliability - The reliability of an independent technical assessment is usually high. The reliability somewhat depends on the quality of the team members, that is, their recoganized level of expertise. While team independence is essential, cooperation and trust between the team and the PMO are also essential. The PMO must provide all required information and the review team must present a balanced picture, while not just focusing on the most negative areas. The major disadvantage of an independent technical assessment is that for a time it can disrupt PMO activities. This is especially true if it points out deficiencies that must be fixed, and there is no time to make the needed fixes prior to an important milestone. The timing of the review is important, therefore, and should be considered in the planning for such reviews.

5.13.3 Independent cost estimates (ICEs). ICEs may be accomplished one or more times for major FAA programs. Because PMOs naturally tend to be optimistic regarding the risks and costs of their programs, particularly in the early stages, an ICE may be directed to provide senior decision-makers with data reflecting an independent viewpoint. The concept is that cost estimators, outside the influence of program advocacy, will develop cost estimates that more accurately portray the challenges, risks, and costs associated with the development and production of advanced systems.

The key aspect of the independent cost estimate is that it is developed in organizational channels separate and independent from the program office. This helps it serve as an analytical tool to validate or cross-check program management office developed cost estimates. This second opinion helps avoid the risk that some significant costs have been overlooked or that PMO program advocacy has resulted in low estimates which could place the success of the program at risk. To the extent that those preparing independent cost estimates are advised and supported by a technical staff independent of the program office staff, some independent assessment of technical risks may also be accomplished during preparation of an independent cost estimate.

5.14 RISK HANDLING TECHNIQUES

Risk handling technique classifications were covered in Section 4.5. The possibilities for dealing with risk are as varied as potential sources of risk. It would be impossible to discuss each technique without first describing the complete circumstances under which it is appropriate. The key to developing an appropriate handling of any risk lies in the proper execution of the risk planning, risk assessment, and risk analysis functions. If these are done properly, the impacts of potential actions will be clearly understood and will lead to the best possible risk handling action.

The following Table 5.14-1 shows some of the typical activities that should be performed in each phase of the development cycle. Clearly, management actions to reduce risk should be aimed at performing quality work on each of these items. One of the primary reasons that this structural approach to acquisition exists is to reduce the risks of buying a piece of equipment that does not meet the need, does not live up to the performance requirement, is too costly, or is too late.

Table 5.14-1 Typical Activities by Program Phase

CONCEPT EXPLORATION	*DEMONSTRATION/VALIDATION*
Identify Manufacturing Technology Needs Identify Critical Materials Evaluate Risk of Manufacturing Alternatives Perform Industrial Base Analysis Determine Contract Requirements for DEM/VAL Define System Level Logistics Requirements (ILSP) Perform Initial Facility Planning Estimate Life Cycle Cost Performance Goals Develop System Specifications Conceptualize T&E Program (TEMP)	Examine Producibility of Competitive Design Prepare for Production Readines Review Prepare Initial Manufacturing Plan Evaluate Long Lead Requirements Determine the Need for LRIP Prepare Initial Production Cost Estimate Determine Contract Requirements for FSD Establish Readiness and Supportability Objectives Prepare for Development and Operational Testing Determine Acquisition Strategy
FULL SCALE DEVELOPMENT	*PRODUCTION*
Define Required Manufacturing Resources Prepare Manufacturing Cost Estimates Perform Production Risk Assessment Accomplish Production Planning Assess Long Lead Material Requirements Perform Producibility Studies Complete Manufacturing Plan Accomplish Development and Operational Testing Perform Production Readiness Reviews Determine Contract Requirements for Production Determine Quality & Performance Controls for Production Evaluate Impact of Engineering Changes on LCC Prepare for Transtition to Production	Ensure Facilities are in Place Examine Use of Warranties Determine Acquisition Strategy Examine Use of Second Source Integrate Spares Production Perform Fielding Analysis Perform Contractor Production Surveillance Execute Product Improvement Initiatives Implement Value Engineering

5.15 CHAPTER 5 KEY POINTS

- Risk Management techniques can apply to multiple parts of the risk management process.
- Some techniques specialize in one aspect of risk.
- Techniques should be selected based on program requirements (Chapter 6 provides detail).
- No technique will give you a choice of management actions.
- Management actions are limited only by the ingenuity of the program manager.

ENDNOTES / REFERENCES

1. "Technical Risk Assessment: Staying Ahead of Real-Time, Technical Problems Visibility and Forecasts (Draft);" Department of the Navy; March 1986.

CHAPTER 6

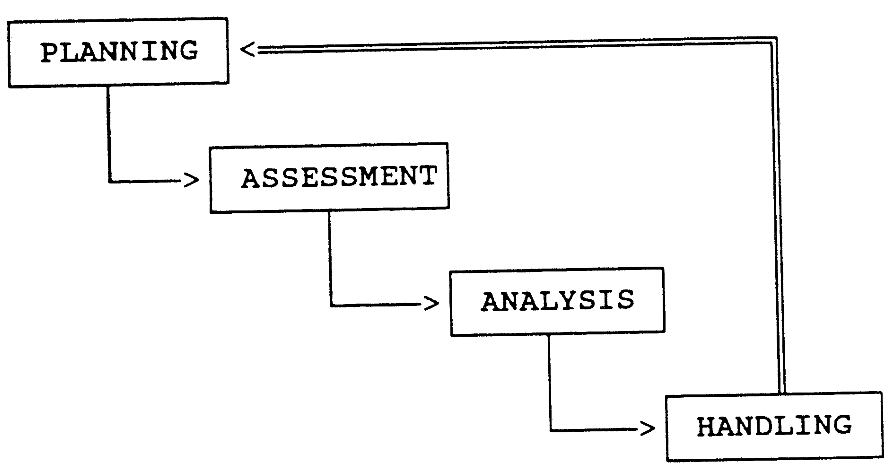
RISK MANAGEMENT IMPLEMENTATION

6. RISK MANAGEMENT IMPLEMENTATION

6.1 INTRODUCTION

While the concepts and techniques of risk planning, assessment, analysis, and handling are complex, the greater challenge is in the actual implementation of the risk management process. Program managers and PMOs are almost categorically overcommitted and overextended. In a recent Risk Analysis and Management survey of DOD Program Management Offices (PMO), allocating the resources to implement an effective risk management program was a significant and frequently reported problems. Over 50 percent of the PMOs responded that inadequate program staffing was a major risk area in and of itself. The view of risk management implementation as an additional requirement levied on the program team can appear as an overwhelming task. In actuality, risk management is an integral part of program management, not an additional analysis task. Risk management affects each of the classic elements of management; planning, organizing, directing, and controlling. Risk management plays an important role in the decision making process. In essence, risk management is a subset of sound program management and while the level or activity may vary, risk management should be viewed as an on-going process versus a one time exercise, as illustrated in Figure 6.1-1.

Figure 6.1-1 Risk Management as a Process



Risk Management implementation means the incorporation of the risk management concepts and techniques into the program management process, not simply the manipulation of a certain model. To this end, this chapter provides guidance for:

(1) Organizing for Risk Management

(2) Technique Selection

(3) Risk Management Resource Allocation

(4) Communicating Risk

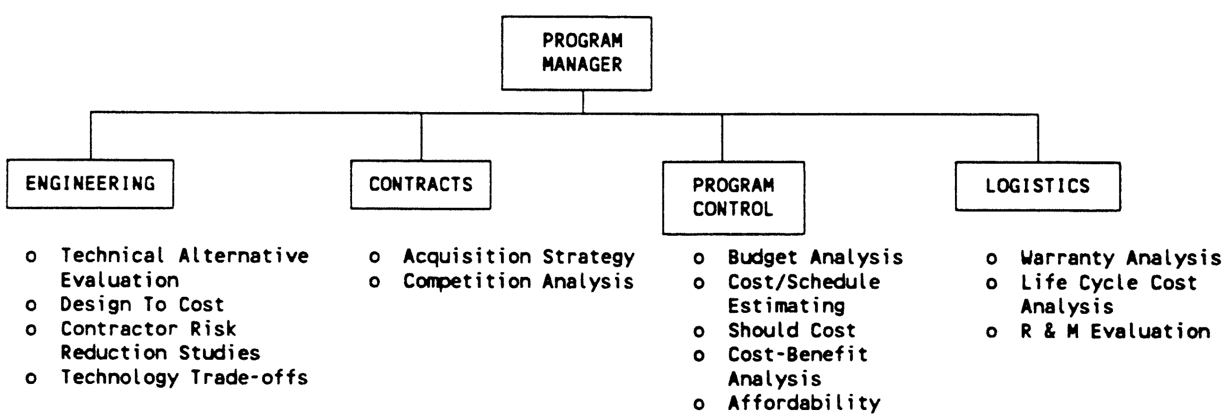
(5) Developing a Risk Management Capability

As with all efforts, successful risk management implementation is a function of the organization's understanding and commitment to meet the challenge.

6.2 ORGANIZING FOR RISK MANAGEMENT

The program manager is ultimately responsible for the implementation of risk management. The program manager establishes goals for the risk management effort and allocates the resources to accomplish these objectives. While the program manager must oversee this process, risk management activities do not reside solely with the program manager. Risk typically manifests itself in the functional analysis and decision making process. Figure 6.2-1 depicts a sample of functional analysis which often involves the complex interplay of technical, programmatic, supportability, cost, and schedule risk. Functional managers must understand the implications risk has in each of their respective disciplines. Risk management is a significant responsibility in each of the functional manager's jobs. The program manager's role is to provide the motivation and structure to effectively manage risk. The program manager should promote the continual interaction between team members for communication concerning risk management.

Figure 6.2-1 Functional Roles In Risk Management



While it is clear that risk management is a team function, it is not obvious how to best organize that team to execute the process. A survey of DOD Program Management Offices risk management activities revealed two basic approaches to organizing for risk management that the respondents felt were successful. One group of PMOs designated specific positions to conduct the program's risk management efforts. The number of people allocated varied by the size of the PMO and the risk management techniques being used. The other PMOs felt that risk management was such an integral part of engineering and management that separate personnel were not designated to manage risk and adequate consideration of risk was being accomplished as a normal part of their jobs.

Either approach could be defended for organizing for risk management. Though different, three basic themes appear as guidelines for incorporating risk management into the program management process. First, the program manager is ultimately responsible, as with all aspects of the program, for the planning, allocation of resources, and execution of risk management. Second, risk management is a team function. Each functional manager plays an important role in the identification, analysis, and handling of risk. Third, risk management activities and responsibilities must be specific and assigned to individuals. Actions and responsibilities assigned to groups are in effect, not assigned. Whether risk management is a full time job or an integral part of a team member's job, risk management actions should be explicit and assignments clear.

6.3 RISK ASSESSMENT AND ANALYSIS TECHNIQUE SELECTION

Establishing objectives and allocating resources to accomplish those objectives is a primary function of the program manager. This function is the basis for risk planning, the first step in the risk management process. At the heart of this planning effort is the selection of the most appropriate risk assessment and analysis techniques for the program. Selection of risk assessment and analysis techniques is the subject of this section. The technique selected shapes the nature of the risk management effort and should be directed towards providing the information necessary to meet the risk management objectives within the resource constraints of the PMO.

This discussion focuses on those risk management techniques described in Chapter 5 that deal specifically with risk assessment and risk analysis. Risk management techniques can be loosely categorized by the primary purpose they serve in the risk management process. Generally, the risk identification and quantification techniques can support a variety of risk assessment and analysis approaches. Expert interviewing techniques are equally applicable for obtaining information in doing a network analysis, decision analysis, or developing a life cycle cost estimate. Similarly, the risk handling technique decision is not a function of the risk assessment methodology employed. Insights from the implementation of a Watchlist, for example, support the use of several approaches to risk handling. The type and timing of information needed for specific decision making applications, however, form the guidelines and constraints for the selection of the appropriate risk assessment and analysis technique. The following section provides guidance and a general framework of comparison for the selection of effective techniques for risk assessment and analysis. The answer is not the same for each program, nor does the answer necessarily stay the same for the life of a single program. The nature and level of risk management activity varies through the acquisition life cycle of a program. The risk assessment and analysis techniques that are effective between Milestone I and II, when a firm technical baseline is not yet established, may be inappropriate in the late production phase of the program. The resources required for risk management activity varies with the techniques, and the techniques used are largely dependent on the objectives of the risk management process.

6.3.1 Technique Selection Criteria

A variety of interrelated factors affect the selection of a technique. The current acquisition phase, size, priority, and complexity of a program all affect the type of information and analysis required to deal with risk. A key consideration and often a major constraint is the availability and capability of resources to devote to risk management. The pressure to do more with less is a constant and pervasive condition in PMOs. Often, organizations also have policies or directives which require the use of one or another risk assessment or analysis technique. The objectives of risk management effort tie these considerations together and balances their influence in the selection of an appropriate technique.

These factors can be aggregated into three categories for the purposes of discussion and technique evaluation and selection (Figure 6.3-1).

(1) Resource requirements

(2) Application

(3) Output

Figure 6.3-1 Risk Management Technique Selection Criteria

RESOURCE REQUIREMENTS	*APPLICATION*	*OUTPUT*
o *COST* o *HARDWARE/SOFTWARE* o *TIME* o *EASE OF USE* o *PM COMMITMENT*	o *PROGRAM STATUS REPORTING* o *MAJOR PLANNING DECISIONS* o *ACQUISITION STRATEGY SELECTION* o *ARC MILESTONE PREPARATION* o *DESIGN GUIDANCE* o *SOURCE SELECTION* o *CIP/BUDGET SUBMITTAL*	o *ACCURACY* o *LEVEL OF DETAIL* o *UTILITY*

Serious consideration of the resources required to execute a particular technique was a recurring theme in the responses to the question of why a particular technique was used by the PMO in the DSMC Risk Management survey results. The second criteria is the application or the decision making process to which the risk assessment or analysis is targeted. The specific purpose or application of the risk information obtained varies and changes. Different techniques better support different applications, thus the application in which the risk information is used is another key criteria category. The third criteria is the actual output from the risk assessment and analysis technique. The accuracy, level of detail, and utility of the technique output should best match the required information for risk management decision making.

The criteria discussed are not all encompassing and clearly other circumstances can influence the selection of a risk technique.

However, these criteria will provide a comparative yardstick for evaluation and a framework for an educated decision to select a technique and implement it in the risk management process.

This section discusses several criteria that can be used to evaluate which risk assessment and analysis technique fits the requirements and constraints of a program's risk management effort. Each of the major techniques is then evaluated against these criteria and a general approach to technique selection is discussed. The intent is not to make technique selection automatic, but to help point out the advantages and disadvantages of different techniques in different circumstances.

6.3.1.1 Resource Requirements

What resources a particular technique requires is often the dominant consideration in the selection process.

The greatest utility with the least time, money, and manpower expended is always the sought after objective. The resource requirements of the various risk assessment and analysis techniques are compared in Table 6.3-1 using the following five factors:

(1) Cost

(2) Hardware/Software Tools needed/available

(3) Time to implement

(4) Ease of Use

(5) PM commitment

The cost identified is a rough approximation of the labor required (in man-months) to conduct or initially set up the risk assessment and analysis. Several techniques are maintained over an extended period of time. The maintenance of these techniques is not considered in the comparative cost figures. Obviously, actual costs vary considerably depending on the size and complexity of the program and the scope of the assessment and analysis. Thus the costs depicted are for comparative purposes. The hardware/software factor simply indicates whether or not (Yes or No) special hardware or software analysis packages are typically needed to use the technique.

Time indicates the duration of time (in months) needed to implement the individual technique. Again, in those techniques requiring continuing maintenance, only the initial time to implement is considered.

Ease of use is a subjective assessment of the relative difficulty in implementing each technique. A three point scale of E (Easy); M (Moderate); and D (Difficult) is used to rate each technique.

The last resource requirement factor examined and rated is the program manager's time commitment to successfully implement the technique. Obviously a technique which requires intensive and continual involvement of the program manager would be difficult to implement. A three point scale of S (Slight); M (Moderate); H (Heavy) is used to rate each technique.

Evaluation of the techniques against each of these factors involved in the resource requirements criteria is presented in Section 6.3.2.

6.3.1.2 Technique Application

The following applications are defined here and matched against the capabilities of the techniques evaluated in Section 6.3.2, using a three point scale of H (High); M (Medium); L (Low).

(1) Program Status Reporting

(2) Major Planning Decisions

(3) Acquisition Strategy Selection

(4) ARC Milestone Preparation

(5) Design Guidance

(6) Source Selection

(7) CIP/Budget Submittal

Program Status Reporting refers to the monitoring of plans, costs, and schedules to ensure that standards are met and problems identified for timely corrective action.

Major Planning Decisions refers to major decisions to which a program manager may be willing to invest significant resources and personal attention.

Acquisition Strategy Selection typically occurs several times throughout the life of a program. Risk assessment and analysis provide key information relevant to the tradeoffs and cost benefit analysis of contract type selection, warranty structuring, etc.

The application of risk assessment and analysis in the *(ARC) Milestone Preparation* is very direct and important. The objective of the ARC is to ensure the major system's planning has been comprehensive and the system is ready to proceed into the next acquisition phase.

The next application category considered in evaluating the techniques is *Design Guidance*. From the consideration of technology alternatives for major systems to the choices of components, each alternative represents a collection of large uncertainties of cost, schedule, and technical performance. In each situation, the program manager will want to understand how the uncertainties relate to one another and how the alternatives compare.

Source Selection evaluations frequently involve the consideration of risk as a determinant of selection. A quantified risk management effort provides the information to substantiate an evaluation. Source selection is a prime application for risk assessment and analysis. The typical short duration of source selections and their necessary restrictive nature place constraints on the type of technique used and the level of detail that can be successfully pursued.

CIP/Budget Submittal is an obvious periodic application category. The basic decision of what funds are required to accomplish the program direction is an exercise in understanding and evaluating the interplay of technical, supportability, programmatic, cost, and schedule risk factors.

6.3.1.3 Technique Output

The third group of factors examined to compare and evaluate risk assessment and analysis techniques consider the output of the risk effort in terms of:

(1) Accuracy

(2) Level of detail

(3) Utility

These factors are defined here and matched against the capabilities of the techniques evaluated in Section 6.3.2 using a three point scale of H (High); M (Medium); and L (Low).

Accuracy deals with the basic theoretical soundness of the technique and the necessity for weakening assumptions which may dilute the value of the information obtained in the analysis. Most techniques present an obvious trade-off between ease of use or time commitment and the final accuracy of the analysis results.

Level of Detail is concerned with the output contents capability to provide more detailed insights into cost, schedule, and technical risks. Techniques and how they are applied vary in the breadth, depth, and understanding that the output contents provide.

Utility is a subjective factor which rates the output in a general context of its usefulness to the PMOs. Both the effort involved in the risk assessment and analysis and the end value of information is considered.

The ratings are obviously subjective, but their discussion brings out important considerations in choosing a risk assessment or analysis technique. The feedback from the DSMC Risk Management survey has been utilized in the rating and comparison of the individual techniques.

6.3.2 Technique Evaluation

This section rates and discusses each of the risk analysis and assessment techniques in the context of the previously defined selection criteria. this presentation will not make the selection of a risk technique automatic. Its intention is to provide the PMOs with an informed perspective to evaluate and choose an approach that is united to meet the objectives of the risk management effort within the ever present resource constraints of a program. Table 6.3-1 is a matrix of the results of evaluating each technique against the previously defined selection criteria.

TABLE 6.3-1 RISK ANALYSIS TECHNIQUE SELECTION MATRIX

	RESOURCE REQUIREMENTS					APPLICATION							OUTPUT		
	COST (MAN-MONTHS)	HARDWARE/ SOFTWARE	TIME (MONTHS)	EASE OF USE	COMMITMENT	PROGRAM STATUS REPORT	MAJOR PLANNING DECISIONS	ACQUISITION STRATEGY SELECTION	DAB MILESTONE PREPARATION	DESIGN GUIDANCE GUIDANCE	SOURCE SELECTION	POM/BUDGET SUBMITTAL	ACCURACY	LEVEL OF DETAIL	UTILITY
NETWORK ANALYSIS	(1) 1-3	Y	(1) 1-3	D	S-M	H	H	M	H	M	H	M	H	L-H	H
DECISION ANALYSIS	.5-1	Y	.2-.6	M	S-M	M	H	H	H	M	M	M	L-H	L-H	M
ESTIMATING RELATIONSHIP	.1	N	.1	E	H	N/A	N/A	N/A	N/A	N/A	N/A	H	L	L	L
TRANSITION TEMPLATES	.5	N	.5	E	M	H	H	H	H	H	L	L	M	M	H
LIFE CYCLE COST ANALYSIS	(1) .1-.3	Y	(1) .1-.5	E	M	H	H	M	M	M	H	H	M	M	H
COST RISK/WBS SIMULATION MODEL	(1) .2-.4	Y	(1) .2-.5	E	S	L	L	N/A	N/A	N/A	L	L	L	L	L
RISK FACTOR METHOD	.1-.4	N/Y	.1-.5	E	S	M	N/A	L	N/A	L	L	M	L	M	M
PERFORMANCE TRACKING	1.5	N/Y	1	E	M	H	M	M	M	H	N/A	M	M	M	H

(1) If appropriate model available, see text.

Y = Yes
N = No

E = Easy
M = Moderate
D = Difficult

S = Slight
M = Moderate
H = Heavy

Application:
H = High
M = Medium
L = Low
N/A = Not Applicable

Output:
H = High
M = Medium
L = Low

Table 6.3-2 Program Phase/Technique Application

	PROGRAM PHASE				INFORMATION YIELD				
	CE	D/V	FSD	PROD	TECH	PROD	SUP	COST	SCHED
EXPERT INTERVIEWS	+	+	+	+	+	0	+	0	0
ANALAGOUS SYSTEMS	0	+	+	+	+	0	0	+	0
PLAN EVALUATION	-	0	+	+	+	0	+	-	-
TRANSITION TEMPLATES/ LESSONS LEARNED STUDIES	0	+	+	+	+	0	+	-	-
NETWORKS	-	+	+	0	+	0	+	+	+
DECISION ANALYSIS	-	+	0	0	0	0	0	0	0
ESTIMATING RELATIONSHIPS	-	-	-	0	-	-	-	+	-
RISK FACTORS	-	0	+	+	-	-	-	+	-
LIFE CYCLE COST MODELS	-	0	0	+	-	-	+	+	-
COST RISK SIMULATIONS	-	-	+	+	-	-	-	+	-
PERFORMANCE TRACKING	0	+	+	+	+	0	+	+	+

- = Relatively weak application/information
0 = Average application/information
+ = Relatively strong application/information

4.1 Complete a risk assessment as outlined above.

4.2 Select the guidelist(s) for the follow-on program phase(s).

4.3 Review the follow-on guidelist(s) to determine which factors could apply to the program in follow-on phases.

4.4 Determine desired risk level for next phase.

4.5 Using both the current phase risk assessment and the desired risk level for the follow-on phases, determine what actions can be taken in the phase under consideration to reduce the risk to the desired level. These actions should be considered in developing the acquisition strategy.

EXAMPLE: Program is in Concept Exploration and preparing to transition to DEM/VAL. The program manager and the program office staff would, therefore, use the DEM/VAL guidelist to assess the program's risk. Assume the program manager is willing to accept a risk rating of medium-high going into DEM/VAL, but wants to be medium-low by the start of EMD and low by the start of production. The EMD and production criteria sheets would be reviewed to determine what actions would need to be done in DEM/VAL to achieve an EMD assessment of medium-low risk, and low going into production. Accomplishing these actions would be part of the program's acquisition strategy.

As noted above, it is the responsibility of each program manager to tailor and further define these criteria according to their unique requirements (space is provided on each sheet to do so). However, it is recommended that program offices use the attached criteria as a guide to assign realistic technical risk ratings to their programs. The program offices should ensure they <u>document</u> their rationale and any assumptions made when assigning a particular risk rating.

APPENDIX N

ENTRY TO PRODUCTION PHASE RISK IDENTIFICATION GUIDELISTS

1. This Appendix provides a set of risk identification guidelists which can be used to determine a program's risk areas. These criteria encompass the areas of requirements, cost/schedule/ management, engineering (hardware and software), acquisition logistics, and manufacturing. The guidelists are tailored to risks which may be encountered in the Production phase. They should be used while in the Engineering and Manufacturing Development (EMD) phase to determine risks that should be addressed as part of the acquisition strategy preparation.

2. Program risk assessment

2.1 Expert judgment. Using available expert judgment, assess the program against each factor. If a factor is not applicable, ignore it.

2.2 Criteria range. This set of criteria covers a broad range, but is not all inclusive. Space is provided on each sheet to identify program-unique factors which can increase or decrease program risks. These factors can be additional factors not listed, or they can be special cases of existing factors.

2.3 Program risk determination. Once the set of criteria sheets is complete, the program manager is responsible for making a final judgment as to the program risks. Note that there is no formula provided to aggregate individual area assessments into an overall risk assessment. Having three low risks, two moderate risks, and one high risk does not automatically mean that one has a moderate risk program. In fact, there have been programs where individually the risk elements were low, but the program became high risk when they were integrated. One needs to take care not to assume that program risk is simply the summation of its individual risk elements. Each program manager remains responsible for assessing the significance of each area, and determining how it influences the overall program risk.

3. Readiness to enter next phase. The risk criteria shown on these sheets are fixed by the status of the design effort, rather than by the phase of the program. The risk ratings (high/moderate/low) are based on the maturity of the program, rather than the phase. It is important to distinguish the absolute risk level from the acceptability of that risk. Acceptability varies from phase to phase. A risk level which is acceptable in DEM/VAL is usually unacceptable in production.

4. Acquisition strategy development. The program manager should follow these steps to incorporate risk considerations in the acquisition strategy.

APPENDIX N

ENTRY TO PRODUCTION PHASE IDENTIFICATION GUIDELISTS

Table M-5 Manufacturing Risk Evaluation Criteria - Entry to EMD Phase

AREA	LOW	MODERATE	HIGH
9. Manufacturing Plan	Detailed planning on fabrication practice/processes development.	Some effort.	Summary level only.
10. Long Lead Funding	Sufficient for projected need.	Marginal.	Insufficient.
11. Built-In Test and Production Testing	Requirements worked together; BIT includes production test capabilities.		Requirements worked separately; BIT does not include production test capabilities.
12. Special Tooling/Test Equipment Planning	Integral part of total manufacturing effort; details available.		Addressed superficially or not at all.
13. Process Characterization Results	Capabilities/limits well defined and meet program goals.	Moderately defined or minor impact on program.	Poorly defined or major program impact.
14. Process Variability	Measured in production environment and meets program goals.	Measured in test environment or minor program impact.	Not measured.
15. Process Proofing - Schedule	Completed prior to initial production.	Conducted concurrent with initial production.	Conducted after initial production.
RISK INCREASING FACTORS:		**RISK REDUCING FACTORS:**	

Table M-5 Manufacturing Risk Evaluation Criteria - Entry to EMD Phase

Page 1 of 2

AREA	LOW	MODERATE	HIGH
1. Industrial Base	Meets all needs (Government/commercial).	Meets Government needs only.	Cannot meet Government needs.
2. Design Producibility	Addressed in design efforts to date.	Assessment in-process; indirect tie to design.	Assessment not done or superficial.
3. Manufacturing Technologies - Use	Proven and acceptable; no development needed.	Low to moderate improvement required.	Significant improvement needed; new technology to be manufactured.
4. Manufacturing Technologies - Development	All needed projects initiated.	Only critical projects initiated.	Not all critical projects initiated.
5. Technologies/Material/Manpower	Available on open market; 2 or more stable sources.	Known source; imitations/instability.	Not available in required amounts.
6. Parts/Assemblies Availability	Commodity item available from multiple sources.	Two sources available.	Single source only.
7. Critical Resource Alternatives (materials, tools, skills, processes)	Readily available.	Available, but long lead impact.	Not available.
8. Technical Manufacturing Plan	Prepared; current and used by contractor.	Prepared as CDRL item and used in Government reviews only.	Compilation of general management/manufacturing practices.
RISK INCREASING FACTORS:		**RISK REDUCING FACTORS:**	

Table M-4 Acquisition Logistics Risk Evaluation Criteria - Entry to EMD Phase

Sheet 2 of 2

AREA	LOW	MODERATE	HIGH
10. Automatic Test Equipment (ATE)	ATE requirements set concurrent with system requirements.	Requirements set concurrent with system design.	Requirements set after system detailed design completed.
11. Support Equipment - Requirements	Defined and funded; both field and depot.	Definition or funding marginal.	Not defined or funded.
12. Support Equipment - Need	Use existing items only.	Minor development or modification required.	Major new design needed.
13. Support Constraints	No major constraints.	One or two major constraints.	More than two major constraints.
14. System/Subsystem Design	Previously used design; no changes.	Modification of previously used design.	New development.
15. Technologies (supportability)	All previously used; support requirements understood.	Some new techniques; initial supportability characterization done.	New technologies; no supportability characterization done.
16. Maintenance Planning	Accomplished at detailed level for each system element.	Top level only.	Not started; maintenance concept only.
17. Maintenance Interfaces	Simple interfaces; no special skills/training needed.	Moderate interfaces; some special skills/training needed.	Complex interfaces; highly skilled personnel needed.
18. Depot Assignments	Completed; made for all system elements.	Major subsystems only; some minor decisions remain.	Not completed for one or more major subsystems.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

Table M-4 Acquisition Logistics Risk Evaluation Criteria - Entry to EMD Phase

Sheet 1 of 2

AREA	LOW	MODERATE	HIGH
1. Deployment Concept	Defined; locations initially identified.	Defined; locations not identified.	Not defined.
2. Operations & Maintenance (O&M Concept)	Fully defined.	Partially defined.	Not defined.
3. Operations & Maintenance Concept	Previously used.	Modified existing.	Not previously used.
4. LSAR "A" Sheet Status	Complete.	Missing one or two requirements.	Missing more than two requirements.
5. Reliability & Maintainability Requirements	<90% of state-of-the-art.	At edge of state-of-the-art (90-100%).	Exceed state-of-the-art (>100%).
6. Supply Support - Requirements	Defined and funded; both field and depot.	Definition or funding marginal.	Not defined or funded.
7. Technical Orders - Requirements	Defined and funded; both field and depot.	Definition or funding marginal.	Not defined or funded.
8. System Diagnostic Requirements.	All aspects (BIT, ATE, manual) set jointly and balanced.	Set as a partially integrated package; some additional balance needed.	Aspects worked independently; over-reliance upon one capability (especially BIT).
9. Built-In Test (BIT) Requirements	BIT requirements set concurrent with system requirements.	Requirements set concurrent with system design.	Requirements set after system detailed design completed.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

Table M-3 Engineering (Hardware/Software) Risk Evaluation Criteria - Entry to EMD Phase

Sheet 3 of 3

AREA	LOW	MODERATE	HIGH
18. HW/SW Interfaces	Clearly defined and formally documented.	Partially defined or some documentation incomplete.	Not defined or clearly documented.
19. Software Size (Estimate)	Less than 50 KDSI.	50-300 KDSI.	Greater than 300 KDSI.
20. Software Simulator	Developed/used for all software.	Developed/used for part of software.	
21. Software Prototyping	Developed, tested and adequately documented for use in EMD.	Partial prototyping; not fully documented.	No prototyping done.
22. Environmental Impact on S/W Design	Little or no impact.	Some impact.	Major impact.
23. Use of Standard Parts/Program Parts List	In place and complete.	In place; missing some classes.	Not in place.
24. Derating Criteria	Comprehensive and in place.	Limited, but in place.	None in place.
25. Man-Machine Interfaces	Not required or use of proven interface	Adaptation of existing interface; no safety critical issues.	Critical interactions with major new development.
26. Hazardous Materials	None required.	Some use; adequate controls in place.	Major use required or inadequate controls.
27. Design Growth Capacity	Margins meet or exceed historical requirements.	Some capacity, but less than historical requirements.	No growth capacity in one or more key areas.
28. Configuration Management	Formal process in place.	Process in place; minor deficiencies.	No process or major deficiencies.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

KDSI = thousands of delivered source instructions

Table M-3 Engineering (Hardware/Software) Risk Evaluation Criteria - Entry to EMD Phase

Sheet 2 of 3

AREA	LOW	MODERATE	HIGH
10. Integration Requirements	Completely defined and funded; no special design issues.	Partially defined or not funded; some unique design problems solutions identified.	Not defined; critical design problems - no solution identified.
11. External Interfaces	Simple and well defined; no unique development required.	Minor development needed or some interfaces need more definition.	Major development and/or major interfaces not defined.
12. Internal Interfaces	Defined; loose coupling between system elements.	More definition needed or some tight coupling.	Major interface ill defined or stringent coupling needed.
13. Operational Environment	Limitations studied/tested; user can tolerate system effects.	Limitations considered, but no formal analysis of effects.	Limitations not addressed.
14. Internal Environmental Effects (operations & support)	Established by test (i.e., vibration, temperature, shock, etc.).	Established by analysis.	Established by use of published data (e.g. military standards, etc.).
15. Software Mode	Batch.	On-line; not timing critical.	Real-time.
16. SW Language	Approved HOL; mature compiler/target.	Non-approved HOL or new compiler/target.	Significant use of assembly; new compile/target.
17. Computational Reserves (memory, timing, IO, etc.)	Requirements less than 50% of capacity.	Requirements between 50-70% of capacity.	Requirements greater than 70% of capacity.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

Table M-3 Engineering (Hardware/Software) Risk Evaluation Criteria - Entry to EMD Phase

AREA	LOW	MODERATE	HIGH
1. System Definition	All system elements defined.	One or two critical system elements not defined.	Three or more critical system elements not defined.
2. Requirements Complexity	Simple; easy to allocate.	Moderately complex, but can be allocated.	Extremely complex; difficult to allocate.
3. System/Subsystem Critical Design Requirements	All identified and analyzed.	Identified, but not completely analyzed.	Not fully identified.
4. Design Requirements Verification	Readily verifiable by test during design process.	Requires long test times at system level.	Not verifiable within program resources.
5. Design for Testing Requirements	Comprehensive set established.	Limited set used in design.	Not considered.
6. Quality Characteristics	Defined for all system elements.	Defined at the system level only.	Not defined.
7. Functional Profiles	Developed; all aspects of system use.	Developed; mission functions only.	Not developed.
8. Technology Demonstration	By experimental/prototype model.	Used in less severe form factor.	Not demonstrated.
9. System/Subsystem Design Demonstration	Proven via prototype or engineering model in relevant environment.	Critical functions only via test.	Verification via analysis only.

RISK INCREASING FACTORS:	RISK REDUCING FACTORS:

Table M-2 Cost/Schedule/Management Risk Evaluation Criteria - Entry to EMD Phase

Sheet 2 of 2

AREA	LOW	MODERATE	HIGH
9. Integration Responsibilities	Defined and funded; controls in place and effective.	Defined, not fully funded; controls still TBD.	Not defined or no funding for integration.
10. Quality Assurance	Planned/implemented.	Planned only.	Not planned.
11. Government-Furnished Information (GFI)	Available to PMO and adequate.	Probably adequate, but must still be developed.	Not adequate; must be developed.
12. Government-Furnished Equipment/Property (GFE/GFP) (Production)	Available from stock; no transportation difficulties.	Must be ordered/manufactured, but lead time 80% or less than time to first need.	Not available or lead time longer than first need date
13. Government-Furnished Equipment/Property (GFE/GFP) (Development)	Available from stock; ready for use in development.	Not readily available, but simulator/work-around available.	Not available; no simulator or work-around available.
14. Key Metrics (risk/performance)	Developed and used.	Developed; process not fully in place.	Not developed.
15. Program Office Staffing	Fully manned; sufficient experience in house.	Manned in all key areas; some training needed.	One or more key areas not manned or manned by inexperienced people.
16. Concurrency - Use of	All system development completed before production started.	Long lead items ordered before qualification completed (on those items).	Major production initiated before testing completed (on those items).
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

Table M-2 Cost/Schedule/Management Risk Evaluation Criteria - Entry to EMD Phase

Sheet 1 of 2

AREA	LOW	MODERATE	HIGH
1. Resource Estimating Tools	Available; used by experienced people.	Available, but limited experience on use.	Not available; not used.
2. Basics for Cost/Schedule Estimating	Extensive database of comparable systems.	Calibrated prediction or limited database.	New system type or technology; no available data.
3. Program Schedule	Sufficient to allow retest/redesign of a reasonable number of failures/problems.	Minimal reserve for retest/redesign.	Based on "all successes"in design validation and testing.
4. Test Scheduling	Based on realistic test rate; adequate margins for retest.	Test rate slightly optimistic; minimal retest margin.	Test rate optimistic; no margins for retest.
5. Test Assets	Sufficient procured, including spares and test schedule overlap.	Marginal number procured.	Insufficient number procured.
6. Test Integration	All tests part of integrated test program.	Some integration of testing.	Test program compilation of independent tests.
7. Funding Availability	Satisfied all planned program activities.	Limits one critical program activity.	Does not allow risk reduction activities.
8. Funding Profile	Adequate for up front development actions.	Marginal for up front development actions.	Insufficient for up front actions.

RISK INCREASING FACTORS:	RISK REDUCING FACTORS:

Table M-1 Requirements Risk Evaluation Criteria - Entry to EMD Phase

AREA	LOW	MODERATE	HIGH
10. Manpower Requirements	All aspects (numbers, skills, training) incorporated into program; program unique factors considered.		Not fully included.
11. Training Requirements	Both human and equipment needs identified; includes embedded and separate training equipment capability.	Partially identified.	Not identified.
12. Support Requirements	Fully identified.	Partially identified.	Not identified.
13. Dependence on Other System Developments	Not dependent on other system developments.	Needs another system which is one development phase ahead.	Needs another system which is in the same development phase.
14. Standards Development (e.g., data exchange formats, electronic compatibility, etc.).	Fully developed.	Exist in draft form; agreement likely.	Need to be created or serious contention on proposed standards.

RISK INCREASING FACTORS:	RISK REDUCING FACTORS:

Table M-1 Requirements Risk Evaluation Criteria - Entry to EMD

Sheet 1 of 2

AREA	LOW	MODERATE	HIGH
1. Requirement Technical Detail Needed	Shallow; at major systems level.	Moderate; general performance parameters.	Detailed; subsystem technical parameters.
2. User Requirements	All stated in quantifiable, testable terms.	Mostly stated in quantifiable requirement terms; some qualitative, vague terms.	Has major requirements expressed in vague, unmeasurable terms.
3. Requirements Freeze (M/S II)	Set fully agreed to.	Partially baselined; minor areas open.	Major disconnects.
4. User Experience With System Type	Much; one-for-one replacement of existing system.	Some or major extension of capability of existing system.	None; new system type for user.
5. User Acceptance	Fully supportive.	Major disagreement within user community.	None; imposed upon user (political, etc.).
6. System Level Requirements	Fully defined and documented.	One critical requirement not defined.	Several critical requirements undefined.
7. System Requirements	Do not exceed 90% of state-of-the-art in any key parameter.	Within 90-100% of state-of-the art in 1 to 3 key parameters.	Exceeds current state-of-the-art in more than 3 key parameters.
8. Design Requirements	Derived from user requirements with audit trail showing translation process.	Derived from user requirements; no audit trail.	User requirements used directly with no translation.
9. System Security (physical, computer).	Fully addressed.	Partially addressed.	Not addressed.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

APPENDIX M

ENTRY TO ENGINEERING AND MANUFACTURING DEVELOPMENT PHASE
RISK IDENTIFICATION GUIDELISTS

This Appendix provides a set of risk identification guidelists which can be used to determine a program's risk areas. These criteria encompass the areas of requirements, cost/schedule/management, engineering (hardware and software), acquisition logistics, and manufacturing.

The guidelists are tailored to risks which may be encountered in the Engineering and Manufacturing Development (EMD) phase. They should be used while in the Demonstration and Validation phase to determine risks that should be addressed as a part of the acquisition strategy preparation.

Detailed instructions on the use of these guidelists can be found in the beginning of Appendix L.

APPENDIX M

ENTRY TO ENGINEERING AND MANUFACTURING DEVELOPMENT PHASE RISK IDENTIFICATION GUIDELISTS

Table L-5 Manufacturing Risk Evaluation Criteria - Entry to Demonstration/Validation

AREA	LOW	MODERATE	HIGH
1. Industrial Base	Meets all needs (Government/ commercial).	Meets Government needs only.	Cannot meet Government needs.
2. Manufacturing Technologies - Use	Proven and acceptable; no development needed.	Low to moderate improvement required.	Significant improvement needed; new technology to be manufactured.
3. Manufacturing Technologies - Development	All needed projects initiated.	Only critical projects initiated.	Not all critical projects initiated.
4. Technologies/Material/ Manpower	Available on open market; 2 or more stable sources.	Known source limitations/ instability.	Not available in required amounts.
5. Design Producibility	Addressed in design efforts to date.	Assessment in process; no direct tie to design.	Assessment not done.
6. Manufacturing Strategy	In-place; all program aspects covered.	In-place; one or two gaps.	Not developed or major gaps.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

Table L-4 Acquisition Logistics Risk Evaluation Criteria - Entry to DEM/VAL Phase

AREA	LOW	MODERATE	HIGH
1. Deployment Concept	Defined; locations initially identified.	Defined; locations not identified.	Not defined.
2. Operations & Maintenance (O&M) Concept	Fully defined.	Partially defined.	Not defined.
3. Operations & Maintenance (O&M) Concept	Previously used.	Modified existing.	Not previously used.
4. System Diagnostic Requirements	All aspects (BIT, ATE, manual) set jointly and balanced.	Set as partially integrated package; some additional balance needed.	Aspects worked independently; over-reliance upon one capability (especially BIT).
5. Technologies (supportability)	All previously used; support requirements understood.	Some new technologies; initial supportability characterization done.	New technologies; no supportability characterization done.
6. Support Constraints	No major constraints.	One or two major constraints.	More than two major constraints.
7. Comparability Analysis	Existing system available.	No existing system, but elements of different existing systems can be combined.	No existing system or elements of different systems available.
8. LSAR "A" Sheet Status	Exist and complete.	Updating existing "A" sheet.	Creating new sheet; new requirements.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

BIT = Built In Test. ATE = Automatic Test Equipment

Table L-3 Engineering (Hardware/Software) Evaluation Criteria - Entry to DEM/VAL Phase

AREA	LOW	MODERATE	HIGH
1. Requirements Complexity	Simple; easy to allocate.	Moderately complex, but can be allocated.	Extremely complex; difficult to allocate.
2. Design/Technological Approach	Identified; analysis shows all critical requirements met.	Identified; analysis not complete, or not all requirements.	Not identified or critical shortfalls.
3. Functional Profiles	Developed; all aspects of system use.	Developed; mission functions only.	Not developed.
4. Operational Environment	Well defined and quantified; design ramifications known.	Specified, but some undefined terms; some design ramifications known.	Undefined; design ramifications unknown.
5. External Interfaces	Simple and well defined; no unique development required.	Minor development needed or some interfaces need more definition.	Major development and/or major interfaces not defined.
6. Technology (development)	Fielded technology only.	New technology (engineering development model exists).	Unproven technology (no engineering development model exists).
7. Technology (form factor)	Previously fielded; same form factor.	Previously fielded; less severe form factor.	Not previously fielded.
8. Technology Transition	Fully transitioned; capability meets user need.	Transition in process; capability relatable to user need.	Transition not begun; capability not up to user needs.
9. Software Size (estimate)	Less than 50 KDSI*.	50 - 300 KDSI*.	Greater than 300 KDSI*.
10. Software Mode	Batch.	On-line; not timing critical.	Real-time.
11. Hazardous Materials	None required.	Some use; adequate controls in place.	Major use required or inadequate controls.
12. Use of Standard Parts/Program Parts List	In place and complete	In place; missing several classes.	Not in place.

<u>RISK INCREASING FACTORS:</u> *KDSI = Thousands of delivered source instructions	<u>RISK REDUCING FACTORS:</u>

Table L-2 Cost/Schedule/Management Risk Evaluation Criteria - Entry to DEM/VAL Phase

AREA	LOW	MODERATE	HIGH
9. Quality Assurance	Planned and implemented.	Planned only.	Not planned.
10. Government-Furnished Information (GFI)	Available to PMO and adequate.	Probably adequate, but must still be developed.	Not adequate; must be developed.
11. Government Furnished Equipment/Property (GFE/GFP) (production)	Available from stock; no transportation difficulties.	Must be reordered/manufactured; but lead time 80% or less than time to first need.	Not available or lead time longer than first need data.
12. Government Furnished Equipment/Property GFE/GFP (development)	Available from stock; ready for use in development.	Not readily available, but simulator/work-around available.	Not available; no simulator or work-around available.
13. Key Metrics (risk/performance)	Developed and used.	Developed; process not fully in place.	Not developed.
14. Program Office Staffing	Fully manned; sufficient experience in-house.	Manned in all key areas; some training needed.	One or more key areas not manned or manned by inexperienced people.
15. Concurrency-Use of	All system development completed before production started.	Long lead items ordered before qualification completed on those items.	Major production initiated before testing completed on those items.

RISK INCREASING FACTORS:

RISK REDUCING FACTORS:

Table L-2 Cost/Schedule/Management Risk Evaluation Criteria - Entry to DEM/VAL Phase

AREA	LOW	MODERATE	HIGH
1. Resource Estimating Tools	Available; used by experienced people.	Available, but limited experience.	Not available; not used.
2. Basis For Cost/Schedule Estimating	Extensive database of comparable systems.	Calibrated prediction or limited database.	New system type or technology; no available data.
3. Program Schedule	Sufficient to allow retest/redesign of a reasonable number of failures/problems.	Minimal reserve for retest/redesign.	Based on "all successes" in design validation and testing.
4. Test Scheduling	Based on realistic test rate; adequate margins for retest.	Test rate slightly optimistic; minimal retest margin.	Test rate optimistic; no margins for retest.
5. Test Assets	Sufficient procured, including spares and test schedule overlap.	Marginal number procured.	Insufficient number procured.
6. Funding Availability	Satisfies all planned program activities.	Limits one critical program activity.	Does not allow risk reduction activities.
7. Funding Profile	Adequate for up front development actions.	Marginal for up front development actions.	Insufficient for up front actions.
8. Integration Responsibilities	Defined and funded; controls in place and effective.	Defined, not fully funded; controls still TBD.	Not defined or no funding for integration.

RISK INCREASING FACTORS:

RISK REDUCING FACTORS:

Table L-1 Requirements Risk Evaluation Criteria - Entry to Demonstration/Validation Phase

AREA	LOW	MODERATE	HIGH
1. Threat Technical Detail Needed	Shallow; at major system level.	Moderate; general performance parameters.	Detailed; subsystem technical parameters.
2. User Requirements	All stated in quantifiable, testable terms.	Mostly stated in quantifiable requirements terms; some qualitative, vague terms.	Has major requirements expressed in vague, unmeasurable terms.
3. Operational Requirements	Fully defined and documented.	One critical requirement not defined.	Several critical requirements undefined.
4. User Experience With System Type	Much; one-for-one replacement of existing system.	Some or major extension of capability of existing system.	None; new system type for user.
5. User Acceptance	Fully supportive.	Major disagreement within user community.	None; imposed upon user (political, etc.)
6. System Requirements	Do not exceed 90% of state-of-the-art in any key parameter.	Within 90-100% of state-of-the-art in 1 to 3 key parameters.	Exceeds current state-of-the-art in more than 3 key parameters.
7. Dependence on Other System Developments	Not dependent on other system development.	Needs another system which is one development phase ahead.	Needs another system which is in the same development phase.
8. Standards Development (e.g., data exchange formats, electronic compatibility, etc.)	Fully developed.	Exist in draft; agreement likely.	Need to be created or serious contention on proposed standards

RISK INCREASING FACTORS:

RISK REDUCING FACTORS:

4. Acquisition strategy development. The program manager should follow these steps to incorporate risk considerations in the acquisition strategy.

4.1 Complete a risk assessment as outlined above.

4.2 Select the guidelist(s) for the follow-on program phase(s).

4.3 Review the follow-on guidelist(s) to determine which factors could apply to the program in follow-on phases.

4.4 Determine desired risk level for next phase.

4.5 Using both the current phase risk assessment and the desired risk level for the follow-on phases, determine what actions can be taken in the phase under consideration to reduce the risk to the desired level. These actions should be considered in developing the acquisition strategy.

EXAMPLE: Program is in Concept Exploration and preparing to transition to DEM/VAL. The program manager and the program office staff would, therefore, use the DEM/VAL guidelist to assess the program's risk. Assume the program manager is willing to accept a risk rating of medium-high going into DEM/VAL, but wants to be medium-low by the start of EMD and low by the start of production. The EMD and production criteria sheets would be reviewed to determine what actions would need to be done in DEM/VAL to achieve an EMD assessment of medium-low risk, and low going into production. Accomplishing these actions would be part of the program's acquisition strategy.

As noted above, it is the responsibility of each program to tailor and further define these criteria according to their unique requirements (space is provided on each sheet to do so). However, it is recommended that program offices use the attached criteria as a guide to assign realistic technical risk ratings to their programs. The program offices should ensure they document their rationale and any assumptions made when assigning a particular risk rating.

APPENDIX L

ENTRY TO DEMONSTRATION/VALIDATION PHASE RISK IDENTIFICATION GUIDELISTS

1. Risk identification guidelists. This Appendix provides a set of risk identification guidelists which can be used to determine a program's risk areas. These criteria encompass the areas of requirements; cost, schedule, and management; engineering (hardware/software); acquisition logistics; and manufacturing.

The guidelists are tailored to risks which may be encountered in the Demonstration/Validation (DEM/VAL) phase. They should be used while in Concept Demonstration to determine risks that should be addressed as a part of the acquisition strategy preparation. Additional sources which can be consulted to create additional program office criteria are listed in Appendix F.

2. Program risk assessment

2.1 Expert judgment. Using available expert judgment, assess the program against each factor. If a factor is not applicable, ignore it.

2.2 Criteria range. This set of criteria covers a broad range, but is not all inclusive. Space is provided on each sheet to identify program-unique factors which can increase or decrease program risks. These factors can be additional factors not listed, or they can be special cases of existing factors.

2.3 Program risk determination. Once the set of criteria sheets is complete, the program manager is responsible for making a final judgment as to the program risks. Note that there is no formula provided to aggregate individual area assessments into an overall risk assessment. Having three low risks, two moderate risks, and one high risk does not automatically mean that one has a moderate risk program. In fact, there have been programs where individually the risk elements were low, but the program became high risk when they were integrated. One needs to take care not to assume that program risk is simply the summation of its individual risk elements. Each program manager remains responsible for assessing the significance of each area, and determining how it influences the overall program risk.

3. Readiness to enter next phase. The risk criteria shown on these sheets are fixed by the status of the design effort, rather than by the phase of the program. The risk ratings (high/moderate/low) are based on the maturity of the program, rather than the phase. It is important to distinguish the absolute risk level from the acceptability of that risk. Acceptability varies from phase to phase. A risk level which is acceptable in DEM/VAL is usually unacceptable in production.

APPENDIX L

ENTRY TO DEMONSTRATION/VALIDATION PHASE RISK IDENTIFICATION GUIDELISTS

Table K-2 Summary Risk Assessment Criteria (Detailed)

PROGRAM RISK LEVEL	MATURITY LEVEL	ENGINEERING	MANUFACTURING	SUPPORT
HIGH	4	Critical functions/ characteristics demonstrated; physical phenomena understood.	Insufficient industrial base capacity.	Support requirements identified. One or more at state-of-the-art limit.
	3	Conceptual design analyses.		
	2	New technology required; state-of-the-art advance. One or more requirements may be unachievable.	Process requires yields/ tolerances/throughput not previously achieved.	New technology required; state-of-the-art advance. One or more requirements may be unachievable.
	1	Conceptual design formulated.	Design uses technology never manufactured previously.	

Table K-2 Summary Risk Assessment Criteria (Detailed)

PROGRAM RISK LEVEL	MATURITY LEVEL	ENGINEERING	MANUFACTURING	SUPPORT
LOW	13	Physical an Functional Configuration Audits (PCA/FCA) successfully completed.	Low rate production successfully done	All ILS elements demonstrated at or above requirements. S/W support facility in place.
	12	Developmental/initial operational testing successfully completed.	Technical data package and process proof test completed.	Support equipment demonstrated. TOs verified.
	11	Design uses only fully qualified existing items. No added development/integration.	Production readiness reviews successfully completed.	Key R&M parameters meet requirements.
MODERATE	10	Qualification testing successfully completed.	Producibility analyses completed. Meet need.	80% of ILS elements demonstrated. Spares provisioned.
	9	Detailed design approved or existing item (qualification needed).	Adequate industrial base capacity available.	TOs validated. Spares long-lead on order.
	8	Engineering model successfully tested in operational environment.	Industrial base capability verified. Yields/tolerances/process controls meet need.	Support Equipment Recommendation Documents (SERDs) all approved.
	7	Prototype or engineering model successfully tested in relevant environments.	Production requirements of new technology defined and demonstrated in lab.	Support requirements of new technology defined and tested.
	6	Preliminary design approved or modified existing design used.	Marginal industrial base capacity (e.g., single source, offshore only, etc.).	Support requirements identified; none exceed 90% of state-of-the-art.
	5	Component/breadboard successfully tested in relevant environments, or one or more requirements only marginally achievable.	Marginal producibilty requirement on one or more aspect of the system.	Support requirements identified; one or more exceed 90% of state-of-the-art.

Table K-1 Summary Risk Assessment Criteria (Standard)

PROGRAM RISK LEVEL	MISSION NEED	COST/SCHEDULE	APPLICATION OF TECHNOLOGY	CAPABILITY OF DEVELOPER
LOW	Technical detail required in the need definition is low (e.g., system level). Need assessment based on observation of existing or soon-to-be-fielded systems.	Allocated funds/ schedule fully adequate to complete the program as defined to meet expected program risks.	Technology used, same form factor, at production rates.	Previously developed similar technology at similar complexity. Capable development processes in place and documented. Personnel have necessary skills. Management capability to successfully complete effort of this magnitude demonstrated.
MODERATE	Technical detail required in the need definition is moderate (e.g., general performance parameters). Need assessment based on known FAA needs, available technology, and observed programs.	Allocated funds/schedule cover basic program. No reserves or marginal reserves to cover expected program risks.	Technology used, but lower form factor. Technology development completed, but never used at production rates.	Previously developed similar technology, but less complex form factor. Some processes in place and documented. Personnel have skills, but these need upgrading. Management capability to successfully complete effort of this magnitude marginal.
HIGH	Technical detail required in need definition is high (e.g., subsystem detailed characteristics). Need assessment based on perceived/projected technology availability.	Insufficient funds/schedule have been allocated to complete the program as defined to meet program risks.	First application of technology. Only laboratory proof of concept tests completed.	Never developed (at specific location) system of this type. Processes not documented. Available personnel/resources do not have required capability. Inadequate management skills to handle effort of this magnitude.

APPENDIX K

SUMMARY TECHNICAL RISK ASSESSMENT

1. Risk evaluation criteria. This Appendix outlines a top-level set of risk evaluation criteria which can be used to determine a program's risk rating and its readiness to enter the next acquisition phase. The requirements, technology, cost, and schedule areas use the standard high/moderate/low rating criteria. For engineering, manufacturing, and support, a more detailed set of criteria are defined. They are based on the concept of design maturity to provide a better level of discrimination between risk levels.

2. Use of tables. To use Table K-1, identify where the program is in relation to the criteria (may be expanded/adapted for specific program circumstances). To use Table K-2, again identify where the program is in relation to the criteria (as expanded by the program office). An important point in using Table K-2 is to remember that the similarity between the preferred system option and existing systems can be used in adjusting the risk assessment. For example, a program proposing to use a considerable amount of existing equipment in proven usage can treat those elements of the program as low risk (assuming the selected equipments meet the program requirements).

The maturity levels in Table K-2 are given to provide additional discrimination in determining a program's risk level. A higher maturity level reflects lower risk. The maturity levels, however, do not have any special quantitative meaning. A maturity level of 8 is not twice as mature as a level of 4.

3. Table criteria. These criteria are definitely not all inclusive. It is the responsibility of each program office to tailor and further define these criteria according to their unique requirements. It is recommended that the program office use the attached criteria as a guide to assign realistic risk ratings to its program. The program office should ensure it documents its rationale and any assumptions made when assigning a particular risk rating.

Once the criteria sheet is complete, the program manager is responsible for making a final judgment as to the overall program risk. Note that there is no formula provided to aggregate the various area assessments into an overall program assessment. Each program manager remains responsible for assessing the significance of each area, and determining how it influences the overall program risk.

APPENDIX K

SUMMARY TECHNICAL RISK ASSESSMENT

Table J-1 Schedule Risk Factors

- o Funding
- o Requirements Definition
  - Statement of Work
  - Work Breakdown Structure
- o Degree of state-of-the-art (how advanced is the system?)
- o Commonality with previous systems
- o Number/historical performance of subcontractors
- o Lead times (materials, etc.)
- o Amount and complexity of software required
- o Number of engineering drawings
- o Schedule managing ability of the contractor
- o Testing requirements
- o Flight tests (number of hours required or number of successful flights)
- o Amount of new materials being used
- o Quality of Government's program office's schedule management
- o Facilities
- o Manpower
- o Equipment
- o Producibility improvements
- o Design/testing requirements
- o Urgency/priority of the program
- o Number of engineering change orders
- o Contractual incentives for meeting program schedule

4.2.3 Continued.

Risk	Optimistic Time	Pessimistic Time
Low	90% of expected time	110% of expected time
Moderate	90% of expected time	140% of expected time
High	90% of expected time	200% of expected time

These ranges have been used on several programs and have been found to be fairly robust. However, they have not proven reliable when the task includes the development of new technology. With new technology, the range will widely, due to the uncertainties inherent in that effort. Do not use these factors in those cases.

5. Summary. The program manager should work diligently to develop a quality program schedule. This action is essential to sound risk management in two ways.

- o First, developing the schedule can identify risk areas not uncovered by other means. This is often the case when a schedule analysis shows that insufficient time or assets have been allocated to the task at hand.

- o Second, a good schedule development effort is useful in determining the appropriate risk handling options to select. If the risk area has sufficient slack time, risk assumption may be appropriate. On the other hand, if the activity is on the critical path, a risk control action may be needed.

Risk management and schedule development go hand in hand. Work them as a team.

Each level of the schedule is built the same way.

4. Risk factors. Assessing the risk factors that affect schedule requires expert judgment. Several areas, however, can be investigated to identify and handle the schedule risk drivers.

4.1 Identify those areas of the schedule where the underlying time estimates are based on limited data. Additional investigation for more data may help.

4.2 Identify and work the critical path. Time estimates for these actions should be scrubbed to ensure they are based on the best data available.

4.3 Evaluate the program for those areas that are the schedule drivers. Table J-1 lists many of the common drivers. Work to refine those estimates.

(1) Conduct sensitivity analyses to determine drivers.

(2) Conduct interviews with subject area experts to identify risk areas.

4.4 Ensure that the schedules properly reflect the interrelationships between functional areas. Many schedule issues arise because of failure to account for inputs and outputs between functional areas. An issue occasionally raised is how to incorporate estimates of risk into a network schedule. Most such programs require the estimator to include an optimistic, most likely, and pessimistic estimate for each task. Sometimes, the estimator has difficulty developing those estimates. There are several actions that can be taken.

4.4.1 First, the estimator can obtain a range estimate from historical variances on similar types of programs.

4.4.2 Second, a range estimate can be derived from a sensitivity analysis of the driving parameters.

4.2.3 Third, if no other options are available, the following factors, based on inherent risk in the effort, can be used.

Management College, ATTN: ATSZ-LSS (Cost/Risk Comm), Fort Lee, VA 23801.

(3) Computer Support Network Analysis Techniques (CSNAS). Order from CSTI/LAT, Wright-Patterson AFB, OH 45433. Phone is (513) 255-6587 (DSN 785-6587).

3.3 Developing a network schedule. In order to apply networking techniques, it is important that certain conditions exist.

(1) The program must consist of clearly defined activities, each with identifiable start and completion points.

(2) The sequence and interrelationships of activities must be determined.

(3) When all individual activities are completed, the program is completed.

The network schedule itself is developed as follows:

3.3.1 Identity all individual tasks that comprise the program.

3.3.2 Determine the expected time to complete each task.

3.3.3 Determine precedence and interrelationships existing among the activities.

3.3.4 Develop a network diagram presenting these activities in proper sequence and reflecting any dependency relationships. Activities are indicated by lines; events or milestones are indicated by circles. Dependency or sequencing relationships among activities on separate paths can be shown by dotted lines (dummy activities).

3.3.5 Compute and annotate the cumulative time required to reach each milestone along the paths, which will indicate earliest time work can start on the next activity. The final number will indicate the total time required to complete a particular path.

3.3.6 Identify critical path. This is the sequence of events, or route, taking longest time to complete.

3.3.7 Starting at the program completion milestone on the right side of the diagram, begin working backward and compute the latest time an activity can start without delaying the overall program. For example, if the total program takes 40 weeks and the last activity requires five weeks, the final activity cannot begin later than week 35. The difference, between the earliest start time and latest time before each activity, is the slack time or float. The critical path contains no slack time, i.e., free time.

3. Development method. The basic tasks for developing a program schedule, for both the milestone and the network techniques, are:

(1) Determine scope of project.

(2) Determine type of scheduling method to be used (milestone, network, other).

(3) Develop a top-level schedule for the program. For most programs, the top-level schedule should not exceed 100 tasks.

(4) Determine all major milestone tasks, durations, interdependencies, and risk through interviews with PMO personnel and outside functional area experts.

(5) Develop lower level detailed schedules using the same techniques.

For the milestone technique, the significant milestones that mark the beginning and end of each program task are identified. These are annotated on the milestone chart. For network schedules, the tasks themselves are placed on the network chart.

3.1 Obtaining time estimates. The estimates for these tasks can be derived in one of four ways:

(1) Through historical data, using the time required for doing similar activities on comparable programs.

(2) Using established estimating factors. Such factors tend to exist for common program tasks (e.g., many test organizations have developed test frequency rates for different types of system level tests).

(3) Using an engineering build-up (most applicable to production estimates). The data used in work measurement systems for production estimates are an example of an engineering build-up schedule estimate.

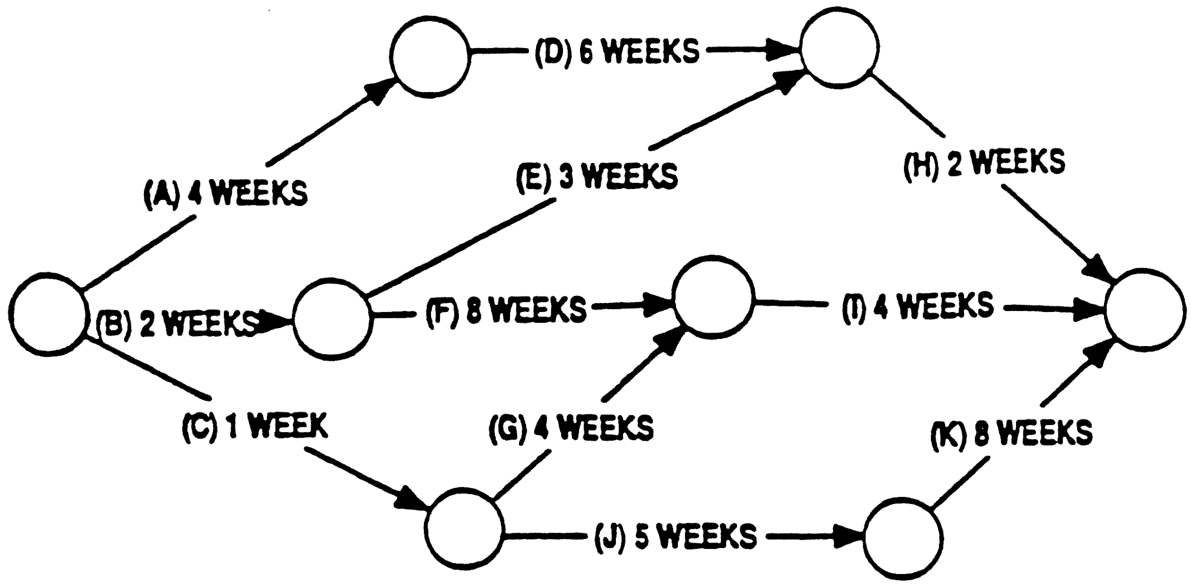
(4) For certain specialized cases, there are parametric schedule estimators, of which COCOMO and SEER (for software schedule estimates) are two popular models.

3.2 Sources for network scheduling software. There are a variety of software available for network scheduling. The following are available from Government sources. They are free to program offices and are PC based.

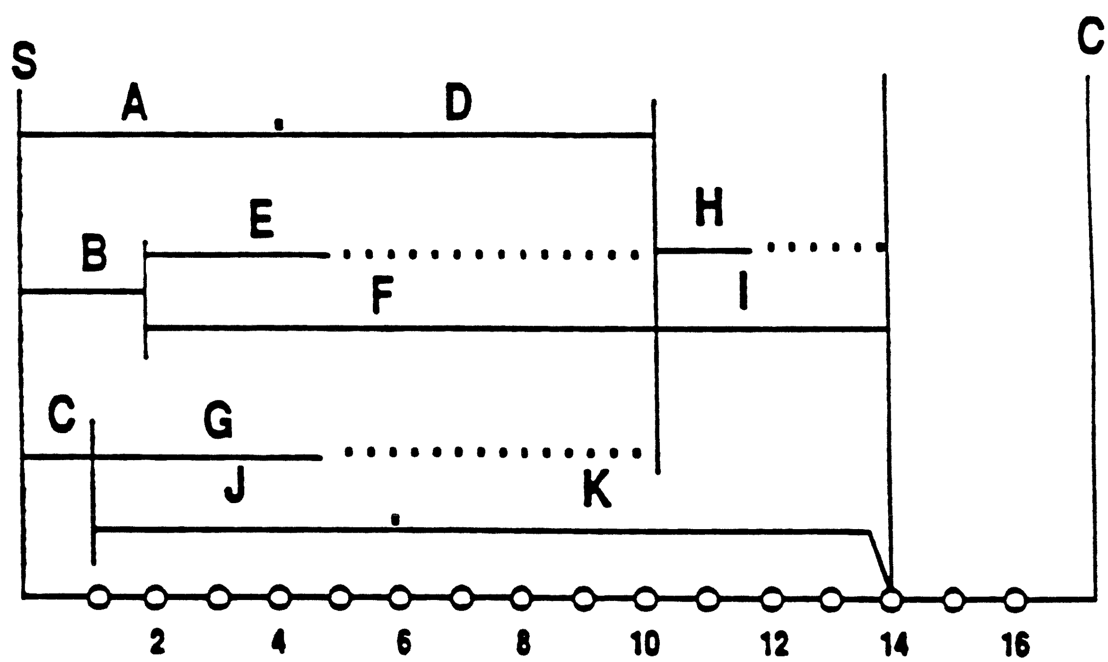
(1) Schedule Risk Assessment Module (SCRAM), Defense Systems Management College. Order by sending request (on Government letterhead), along with one blank 5.25 or 3.5 inch low density disk, to DSMC, DSD (Software Distribution Center), Fort Belvoir, VA 22060-5264.

(2) Venture Evaluation and Review Technique (VERT). Allows the incorporation of event probabilities, cost and resource considerations. Order from Commandant, U.S. Army Logistics

Figure J-1. Network Chart (Example)



NETWORK LAYOUT



CONVERSION TO MILESTONE CHART

b. Considering all of the program segments, which segments must be finished on time to avoid missing the scheduled completion date?

c. Can resources be shifted to critical parts of the program (those that must be completed on time) from non-critical parts (those that can be delayed) without affecting the overall scheduled completion date for the program?

d. Among the myriad program tasks, where should management efforts be concentrated at any particular time?

Most activities in a network take a long time to accomplish; therefore, time is usually expressed in days or weeks. Because of the uncertainty associated with programs which have not been done in the same way before, the expected time for an activity is often described by a probability distribution, rather than a single estimate. The characteristics of the distribution used to express the variation in time are:

a. A small probability (~0.05) of reaching the most optimistic time (shortest time), time "a".

b. A small probability (~0.05) of reaching the most pessimistic time (longest time), time "b".

c. The most likely time which would fall between the two extremes above, time "m".

d. The ability to measure uncertainty in the schedule estimate.

Because it has all four attributes, the beta distribution was chosen for determining the expected time. The three time estimates shown may be combined into a single workable time value. The expected time for an activity can be found by using the following weighted average formula:

$$t = \frac{a + 4m - b}{6}$$

where t is the expected time.

An example network is shown in Figure J-1. Note that networks can be converted to milestone charts. However, for most programs with any detail, the network should be created and maintained in a computer data base. Section 3.2 below lists several software packages available free from Government sources.

The milestone chart records the manager's assessment. For example, a manager might reasonably predict that a one-month slip in the start of software development will probably result in a several-month slip in completing the engineering development phase. The milestone chart does not provide the assessment; the manager's experience does. This is the key to understanding the use of milestone charts. Unless the activity and interrelationships of milestones are understood, the chart tells only what has happened. With his experience and knowledge, the program manager can predict more accurately what will occur in the future. The milestone scheduling technique shows what is scheduled, what has happened, and changes in plans. The technique is not as useful for forecasting schedule changes as is the network technique discussed below. Milestone charting represents a simple and effective means to display the actual versus the planned progress of a program, and to show schedule changes that have occurred. These charts emphasize start and completion dates, rather than the activities that take place between these dates.

Although milestone charts are used on complex programs, they are usually the product of network analysis. Milestone chart preparation is relatively simple, but developing and analyzing the information going in to the charts can be time consuming. A controlled flow of accurate, timely, and appropriate information is important.

2.2 Network schedules. Shortcomings in milestone charts gave rise in the 1950's to network scheduling. The network techniques provided a means to graphically display information for program managers that could not be presented with bars or milestones. An extremely useful tool, for both schedule estimating and for assessing program risks, program network schedules use concepts originally established by the Program Review and Evaluation Technique (PERT), and expanded by a variety of scheduling tools (See Section 3.2)

To analyze a program, it is separated into activities. Each activity is based on a particular undertaking and each is defined by a distinct start and completion point. The program office lays out the tasks that must be accomplished, determines the order in which the tasks must be done, and estimates how long it will take to do each task. To get a truly integrated schedule, the program office and the contractor(s) must take care to clearly define all the tasks and identify their interfaces, inputs/outputs, and estimated duration. In any network model, the overall program schedule is based on the length of time needed for each activity within the schedule.

Network scheduling provides a method for finding the longest time-consuming path. This gives the program manager two important tools. First, he/she is able to more accurately estimate the total time from program start to completion. Second, by being able to identify items on the critical (or longest) path as opposed to tasks less critical, the manager is able to analyze problems as they arise. In addition, network schedules help the program manager answer such questions as:

a. When is each segment of the program scheduled to begin and end?

APPENDIX J

SCHEDULE DEVELOPMENT

1. General. Developing the program schedule is one of the most critical activities that the program office will undertake. Once published, the schedule will become one of the two major score cards (the other is cost) that the program office will be measured against. Despite this importance, there is little written on how to develop an effective program office schedule, or how to assess the risks inherent in that schedule. This Appendix makes a small stab at filling that vacuum.

2. Techniques. There are a number of scheduling techniques available that may be applicable to program management. The most common are bar (Gantt) schedules, milestone schedules, network schedules, and line-of-balance schedules. A comparison shows that bar and milestone schedules are very similar; therefore, only milestone schedules will be discussed below. In addition, the line-of-balance technique is applicable only to production programs, and will not be discussed below.

2.1 Milestone schedules. Milestone scheduling is a popular technique used in FAA program management offices. The technique is relatively simple. Milestone schedules are event oriented. For a particular program, a set of key events, or milestones, is selected. A milestone is a scheduled event that will occur when a particular activity is started or complete. Milestones are selected from the program's acquisition strategy. By reviewing the status of key milestones, one can assess quickly the overall program status.

The milestone schedule chart is an effective method of communication. The symbology is relatively standard and simple to use. The chart presents actual progress against a baseline plan and displays changes in plans. The mechanics of constructing a milestone chart are relatively easy. Contractors use milestone charts so extensively that they have become a denominator in program management. Milestone charts have an important drawback; however, they invite surprises. A surprise can occur when the number of displayed milestones is too limited or when interdependencies are not portrayed. The result may be that the program manager does not know the status of a key event until it occurs, or until it fails to occur when scheduled. A potential problem arises if a program manager focuses on a relatively simple milestone format. He may lose sight of the complexity of the relationships among various program tasks. A well-conceived milestone status report can provide early warning of a potential problem. Early problem recognition is a key to successful program management.

The milestone scheduling technique uses a symbology consisting of arrows and diamonds, open and closed deltas, or similar designators, to show originally planned event dates, accomplishments or modified dates. Arrows are used to show rescheduled events, while diamonds indicate the originally planned schedule. As a result, the milestone schedule allows us to retain the baseline dates, while incorporating changes in planned future events.

APPENDIX J

SCHEDULE DEVELOPMENT

APPENDIX I

RESERVED

APPENDIX H

RESERVED FOR

SPECIAL NOTES ON COMPUTER HARDWARE RISK

Table G-5 Quantification of Probability and Impact of Schedule Failure

	MAGNITUDE		
SCHEDULE DRIVERS	LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
REQUIREMENTS			
DEFINITION	Known; baseline.	Baselined; some unknowns.	Unknown; no baseline.
STABILITY	Little or no change projected.	Controllable change projected.	Rapid or uncontrollable change.
COMPLEXITY	Compatible with existing technology.	Some dependency on new technology.	Incompatible with existing technology.
IMPACT	Realistic; achievable schedule.	Possible slippage in IOC.	Unachievable IOC.

Table G-5 Quantification of Probability and Impact of Schedule Failure

	MAGNITUDE		
SCHEDULE DRIVERS	LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
RESOURCES			
PERSONNEL	Good discipline mix in place.	Some disciplines not available.	Questionable mix and/or availability.
FACILITIES	Existent; little or no modification.	Existent; some modification.	Nonexistent; extensive changes.
FINANCIAL	Sufficient budget allocated.	Some questionable allocations.	Budget allocation in doubt.
NEED DATES			
THREAT	Verified projections.	Some unstable aspects.	Rapidly changing.
ECONOMIC	Stable commitments.	Some uncertain commitments.	Unstable; fluctuating commitments.
POLITICAL	Little projected sensitivity.	Some limited sensitivity.	Extreme sensitivity.
GFE/GFP	Available; certified.	Certification or delivery questions.	No application evidence.
TOOLS	In place; available.	Some deliveries in question.	Little or none.
TECHNOLOGY			
AVAILABILITY	In place.	Baselined; some unknowns.	Unknown; no baseline.
MATURITY	Application verified.	Controllable change projected.	Rapid or uncontrolled change.
EXPERIENCE	Extensive application.	Some dependency on new technology.	Incompatible with existing technology.

Table G-4 Quantification of Probability and Impact of Cost Failure Page 2 of 2

	MAGNITUDE		
COST DRIVERS	LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
TOOLS AND ENVIRONMENT			
FACILITIES	Little or no modifications.	Some modifications;, existent.	Major modifications;, nonexistent.
AVAILABILITY	In place; meets need dates.	Some compatibility with need dates.	Nonexistent; does not meet need dates.
RIGHTS	Compatible with PDSS and development plans.	Partial compatibility with PDSS and development plans.	Incompatible with PDSS and development plans.
CONFIGURATION MANAGEMENT	Fully controlled.	Some controls.	No controls.
IMPACT	Sufficient financial resources.	Some shortage of financial resources; possible overrun.	Significant financial shortages; budget overrun likely.

Table G-4 Quantification of Probability and Impact of Cost Failure

	MAGNITUDE		
COST DRIVER	LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
REQUIREMENTS			
SIZE	Small; non-complex or easily decomposed.	Medium; moderate complexity; decomposable.	Large; highly complex or not decomposable.
RESOURCE CONSTRAINTS	Little or no hardware imposed constraints.	Some hardware imposed constraints.	Significant hardware imposed constraints.
APPLICATION	Non real-time; little system interdependency.	Embedded; some system interdependency.	Real-time; embedded; strong interdependency.
TECHNOLOGY	Mature; existent; inhouse experience.	Existent; some inhouse experience.	New or new application; little experience.
REQUIREMENTS STABILITY	Little or no change to established baseline.	Some change in baseline expected.	Rapidly changing or no baseline.
PERSONNEL			
AVAILABILITY	In place; little turnover expected.	Available; some turnover expected.	High turnover; not available.
MIX	Good mix of software disciplines.	Some disciplines inappropriately represented.	Some disciplines not represented.
EXPERIENCE	High experience ratio.	Average experience ratio.	Low experience ratio.
MANAGEMENT ENGINEERING	Strong management approach.	Good personnel management approach.	Weak personnel management approach.
REUSABLE SOFTWARE			
AVAILABILITY	Compatible with need dates.	Delivery dates in question.	Incompatible with need dates.
MODIFICATIONS	Little or no change.	Some change.	Extensive changes.
LANGUAGE	Compatible with system and PDSS requirements.	Partial compatibility with requirements.	Incompatible with system or PDSS requirements.
RIGHTS	Compatible with PDSS and competition requirements.	Partial compatibility with PDSS; some competition.	Incompatible with PDSS concept; noncompetitive.
CERTIFICATION	Verified performance; application compatible.	Some of application compatible with PDSS; some competition.	Unverified; little test data available.

Table G-3 Quantification of Probability and Impact of Support Failure Page 2 of 2

	MAGNITUDE		
SUPPORT DRIVERS	LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
<u>SUPPORTABILITY</u>			
CHANGES	Within projections	Slight deviations	Major deviations
OPERATIONAL INTERFACES	Defined, controlled	Some "hidden" linkages	Extensive linkages
PERSONNEL	In place, sufficient, experience	Minor discipline mix concerns	Significant concerns
RELEASE CYCLE	Responsive to user requirements	Minor incompatibilities	Nonresponsive to user needs
PROCEDURES	In place, adequate	Some concerns	Nonexistent or inadequate
<u>IMPACT</u>	Responsive software support	Minor delays in software modifications	Nonresponsive or unsupportable software

Table G-3 Quantification of Probability and Impact of Support Failure

	MAGNITUDE		
SUPPORT DRIVERS	LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
DESIGN			
COMPLEXITY	Structurally maintainable.	Certain aspects difficult.	Extremely difficult to maintain.
DOCUMENTATION	Adequate.	Some deficiencies.	Inadequate.
COMPLETENESS	Little additional for PDSS incorporation.	Some PDSS incorporation.	Extensive PDSS incorporation.
CONFIGURATION MANAGEMENT	Sufficient; in place.	Some shortfalls.	Insufficient.
STABILITY	Little or no change.	Moderate; controlled change.	Rapid or uncontrolled change.
RESPONSIBILITIES			
MANAGEMENT	Defined; assigned responsibilities.	Some roles and mission issues.	Undefined or unassigned.
CONFIGURATION MANAGEMENT	Single point control.	Defined control points.	Multiple control points.
TECHNICAL MANAGEMENT	Consistent with operational needs.	Some inconsistencies.	Major inconsistencies.
CHANGE IMPLEMENTATION	Responsive to user needs.	Acceptable delays.	Nonresponsive to user needs.
TOOLS & MANAGEMENT			
FACILITIES	In place;, little change.	In place;, some modification.	Nonexistent or extensive change.
SOFTWARE TOOLS	Delivered; certified; sufficient.	Some resolvable concerns.	Not delivered, certified, or sufficient.
COMPUTER HARDWARE	Compatible with "ops" system.	Minor incompatibilities.	Major incompatibilities.
PRODUCTION	Sufficient for fielded units.	Some capacity questions.	Insufficient.
DISTRIBUTION	Controlled; responsive.	Minor response concerns.	Uncontrolled or nonresponsive.

Table G-2 Quantification of Probability and Impact of Operational Failure Page 1 of 1

	MAGNITUDE		
OPERATIONAL DRIVERS	LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
USER PERSPECTIVE			
REQUIREMENTS	Compatible with the user environment.	Some incompatibilities.	Major incompatibilities with "ops" concepts.
STABILITY	Little or no change.	Some controlled change.	Uncontrolled change.
TEST ENVIRONMENT	Representative of the user environment.	Some aspects are not representative.	Major disconnects with user environment.
OT&E RESULTS	Test errors/failures are correctable.	Some efforts/failures are not correctable before IOC.	Major corrections necessary.
QUANTIFICATION	Primarily objective.	Some subjectivity.	Primarily subjective.
TECHNICAL PERFORMANCE			
USABILITY	User friendly.	Mildly unfriendly.	User unfriendly.
RELIABILITY	Predictable performance.	Some aspects unpredictable.	Unpredictable.
FLEXIBILITY	Adaptable with threat.	Some aspects are not adaptable.	Critical functions not adaptable.
SUPPORTABILITY	Timely incorporation.	Response times inconsistent with need.	Unresponsive.
INTEGRITY	Responsive to update.	Hidden linkages; controlled access.	Insecure.
PERFORMANCE ENVELOPE			
ADEQUACY	Full compatibility.	Some limitations.	Inadequate.
EXPANDABILITY	Easily expanded.	Can be expanded.	No expansion.
ENHANCEMENTS	Timely incorporation.	Some lag.	Major delays.
THREAT	Responsive to change.	Cannot respond to some changes.	Unresponsive.
IMPACT	Full mission capability.	Some limitations on mission performance.	Severe performance limitations.

Table G-1 Quantification of Probability and Impact of Technical Failure

	MAGNITUDE		
TECHNICAL DRIVERS	LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
DEVELOPMENTAL APPROACH			
PROTOTYPES & REUSE	Used; documented sufficiently for use.	Some use and documentation.	No use and/or no documentation.
DOCUMENTATION	Correct and available.	Some deficiencies; available.	Nonexistent.
ENVIRONMENT	In place; validated; experience with use.	Minor modifications; tools available.	Major development effort.
MANAGEMENT APPROACH	Existing product and process controls.	Product and process controls need enhancement.	Weak or nonexistent.
INTEGRATION	Internal and external controls in place.	Internal or external controls not in place.	Weak or nonexistent.
IMPACT	Minimal to small reduction in technical performance.	Some reduction in technical performance.	Significant degradation to nonachievement of technical performance.

Table G-1 Quantification of Probability and Impact of Technical Failure Page 1 of 2

	MAGNITUDE		
TECHNICAL DRIVERS	LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
REQUIREMENTS			
COMPLEXITY	Simple or easily allocatable.	Moderate; can be allocated.	Significant or difficult to allocate.
SIZE	Small or easily broken down into work units.	Medium or can be broken down into work units.	Large or cannot be broken down into work loads.
STABILITY	Little or no change to baseline.	Some change in baseline expected.	Rapidly changing or no baseline.
PDSS	Agreed to support concept.	Roles and missions issues unresolved.	No support concept or major unresolved issues.
R&M	Allocatable to hardware and software components.	Requirements can be defined.	Can only be addressed at the total system level.
CONSTRAINTS			
COMPUTER RESOURCES	Mature; growth capacity within design; flexible.	Available; some growth capacity.	New development; no growth capacity; inflexible.
PERSONNEL	Available; in place; experienced; stable.	Available, but not in place; some experience.	High turnover; little or no experience; not available.
STANDARDS	Appropriately tailored for application.	Some tailoring; all not reviewed for applicability.	No tailoring; none applied to the contract.
GFE/GFP	Meets requirements; available.	May meet requirements; uncertain availability.	Not compatible with system requirements; unavailable.
ENVIRONMENT	Little or no impact on design.	Some impact on design.	Major impact on design.
TECHNOLOGY			
LANGUAGE	Mature; approved HOL used.	Approved or non-approved HOL.	Significant use of assembly language.
HARDWARE	Mature; available.	Some development or available.	Total new development.
TOOLS	Documented; validated; in place.	Validated; some development.	Unvalidated; proprietary; major development.
DATA RIGHTS	Fully compatible with support and follow-on.	Minor incompatibilities with support and follow-on.	Incompatible with support and follow-on.
EXPERIENCE	Greater than 3 to 5 years.	Less than 3 to 5 years.	Little or none.

software development problems. The basic process for risk management still applies to software - plan, assess, analyze, and handle. Tables G-1 to G-5 are extracts from the draft AFSC pamphlet that may prove useful in quantifying software risk. The "Software Reporting Metrics" document has proven extremely useful. Both the Army and Air Force have issued formal guidance regarding the use of this technique.

APPENDIX G

SPECIAL NOTES ON SOFTWARE RISK

1. General. While the techniques and processes discussed in the text of the guide do apply to software, they do not address some of the peculiarities that are a part of software development. Software has a tendency to change dramatically during the development cycle, when compared to hardware. This Appendix is intended to generate some thought and suggest some useful actions in managing software development efforts. Additional information can be obtained from Chapter 20 of the DSMC Systems Engineering Management Guide.

2. Software Quality Assurance program. One of the most effective risk management (handling) techniques for software is the establishment of a formal Software Quality Assurance program early in the development cycle. The program should establish a team of experts whose charter is to explicitly look at issues which will ensure a reliable product in a reasonable time and at a reasonable cost. Some of the issues that the team must evaluate include the following:

- Is independent verification and validation warranted?
- Is the development environment adequate (tool sets, compiler)?
- Is the higher order language selection appropriate?
- Are the requirements clearly stated?
- Will rapid prototyping be used?
- Has the software approach been baselined?
- Has the testing philosophy been established?
- Has the development philosophy been established?

Addressing these issues early in the development cycle will help avoid surprises downstream. There are three documents that may provide useful information for software risk management:

(1) AFSC 800-XX (Draft), Air Force System Command Software Risk Management, June 1987.

(2) ASD Pamphlet 800-5 Acquisition Management, Software Development Capability/Capacity Review, 10 September 1987.

(3) Software Reporting Metrics, Electronic Systems Division, AFSC, Hanscom AFB, MA, November 1985.

These documents contain more specific actions for dealing with

APPENDIX G

SPECIAL NOTES ON SOFTWARE RISK

of capturing expert judgment is "expert support systems." Ideally, the expert support system would lead the expert(s) through a series of parameter specific questions (cost and schedule, possibly performance) and generate PDFs based on the responses.

3. Resource requirements. The effort required to conduct expert interviews and generate appropriate PDFs is man-hour intensive. Much time is spent by the analyst with the expert(s) acquiring and quantifying their expertise. The amount of time required to accomplish this task is predicated on the number of PDFs needed (based on the number of activities required as model input and whether cost, schedule, and technical distributions are required). The methods described are basically manual with computer resources not a necessity. However, as the techniques become more complex and expert support systems to accomplish the tasks are developed, computer resources required will escalate dramatically.

4. Reliability. The reliability of the PDFs obtained through these techniques is affected by a number of factors. Foremost is the degree to which the so called "expert" is in fact an expert. The better understanding the expert has of the parameter being modeled, the more reliable the resulting PDFs will be. The burden also falls on the analyst to select the technique most appropriate for obtaining PDFs. For example, if expertise resides with more than one expert, a Delphi technique would result in much more reliable PDFs than would a direct method asking only one expert. Likewise, if the expert has very little understanding of probability concepts, it would be inappropriate to ask him to select a PDF from a visual list of options. Under these circumstances, the modified Churchman-Ackoff method or a betting technique would most likely result in more reliable PDFs. In summary, much of the reliability of the PDFs is predicated on the techniques selected by the analyst for constructing them. Therefore, it is important that the analyst know when each technique is most appropriate, given the unique circumstances of that specific program office.

misconception. Too often the term is used to identify a committee or multiple interview process; however, these do not share the advantages of the Delphi technique.

The Delphi technique has been extended in recent years to cover a wide variety of types of group interaction. The technique can be used for group estimation, that is, the use of a group of knowledgeable individuals to arrive at an estimate of an uncertain quantity. The quantity can be a cost, a time period associated with an event, or a performance level. The Delphi technique is most appropriate when:

- The problem does not lend itself to precise analytical techniques, but can benefit from subjective judgments on a collective basis.
- The individuals needed to contribute to the examination of a broad or complex problem have no history of inadequate communication and may represent diverse backgrounds with respect to experience or expertise.
- More individuals are needed than can effectively interact in a face-to-face exchange.
- Time and cost make frequent group meetings unfeasible.
- The efficiency of face-to-face meetings can be increased by a supplemental group communication process.
- Disagreements among individuals are so severe or politically unpalatable that the communication process must be referred and/or anonymity assured.
- The heterogeneity of the participants must be preserved to assure validity of the results, i.e., avoidance of domination by quantity or by strength of personality ("bandwagon effect").

The Delphi technique differs from other methods of obtaining a group opinion, because it physically separates the group's members from one another in order to reduce irrelevant interpersonal influences. Properly carried out, the technique is facilitated by an analyst obtaining each panel member's opinion and each member's reason for the opinion. The analyst then reduces the opinions and reasons to standard statements in order to preserve anonymity. The analyst then shows the panel member the aggregated opinions of the other panel members in statistical terms. The analyst provides each panel member with the reasons justifying the opinions that differ with the member, and requests revaluation and further substantiation. This iterative feeding back continues until no further substantial change results. At this point, the moderator takes the final individual opinions and computes a set of median values to represent the group opinion. The median value, rather than the average, is used as a central estimate to present the estimate from being overly influenced by extreme individual values.

One technique which holds much promise for the future as a means

$$P(X_1) + \frac{80}{100}P(X_1) + \frac{50}{100}P(X_1) + \frac{25}{100}P(X_1) + \frac{10}{100}P(X_1) = 1.0$$

Solving this equation, P(X1) = 0.377. This value can be used to determine the remaining probabilities as follows:

$$P(X_2) = \frac{RX_2}{RX_1} P(X_1) = 0.80\ (0.377) = 0.301$$

$$P(X_3) = \frac{RX_3}{RX_1} P(X_1) = 0.50\ (0.377) = 0.189$$

$$P(X_4) = \frac{RX_4}{RX_1} P(X_1) = 0.25\ (0.377) = 0.095$$

$$P(X_5) = \frac{RX_5}{RX_1} P(X_1) = 0.10\ (0.377) = 0.038$$

$$P(X_6) = \frac{RX_6}{RX_1} P(X_1) = 0.00\ (0.377) = 0.000$$

$$P(X_7) = \frac{RX_7}{RX_1} P(X_1) = 0.00\ (0.377) = 0.000$$

The resulting probability density appears in Table F-5.

Table F-5 Probability Density

COMPONENT CHARACTERISTIC VALUE	PROBABILITY
X_1	0.377
X_2	0.301
X_3	0.189
X_4	0.095
X_5	0.038
X_6	0.000
X_7	0.000

	TOTAL 1.000

5. Delphi Approach. In many cases, expert judgment does not reside solely with one individual, but is spread among multiple experts. Committee approaches to obtaining a group assessment have been found to contain problems relating to interpersonal pressures to a degree that caused researchers at the RAND Corporation to devise a method known as the Delphi to avoid the pressures. The Delphi technique has become well known in management circles, but is subject to

for X_4 with respect to X_1, X_2, and X_5. As a result of this process, the relative probability values shown in Table F-4 might be attained.

Table F-4 Relative Probability Ratings

RX_1	=	100 Probability points
RX_2	=	80 Probability points
RX_3	=	50 Probability points
RX_4	=	25 Probability points
RX_5	=	10 Probability points
RX_6	=	0 Probability points
RX_7	=	0 Probability points

Finally, the scale of relative probability values can be converted directly into a scale of actual probability density values by letting $P(X_1)$ equal the actual subjective probability or occurrence of the highest value. Then, $P(X_2)$ is then defined as:

$$\frac{R(X_2)}{R(X_1)}\,[P(X_1)]$$

Similarly $P(X_i)$ is defined as:

$$\frac{R(X_i)}{R(X_1)}\,[P(X_1)]$$

for i = 2, 3, ..., 7.

Assuming that the independent characteristic values evaluated represent all possible values attainable by the component characteristic, the respective probabilities must sum to 1.0 (i.e., $P(X_1) + P(X_2) + P(X_3) + P(X_4) + P(X_5) + P(X_6) + P(X_7) = 1.0$). Substituting the expressions for $P(X_i)$, i=2,..., 7, it follows that:

$$P(X_1) + \frac{R(X_2)}{R(X_1)}[P(X_1)] + \frac{R(X_3)}{R(X_1)}[P(X_1)] + \frac{R(X_4)}{R(X_1)}[P(X_1)] + \frac{R(X_5)}{R(X_1)}[P(X_1)]$$

$$+ \frac{R(X_6)}{R(X_1)}[P(X_1)] + \frac{R(X_7)}{R(X_1)}[P(X_1)] = 1.0$$

Solving this equation for $P(X_1)$, the remaining $P(X_i)$, i= 2, ..., 7 can be determined using the relationship:

$$P(X_1) = \frac{R(X_i)}{R(X_1)}\,[P(X_1)]$$

As an illustration, consider the relative probability ratings in Table F-4. Using the values, the preceding equation is given by:

List the values in descending order of simple ordinal probability preference and change the symbols for each value from 0_i to X_j as shown in Table F-3.

Table F-3 Transformation

CHARACTERISTIC VALUE (DAYS)		PREFERENCE RANK	NEW SYMBOL
0 - 3	0_4	1	X_1
4 - 7	0_3	2	X_2
8 - 11	0_5	3	X_3
12 - 15	0_2	4	X_4
16 - 19	0_6	5	X_5
20 - 23	0_1	6	X_6
24 - 27	0_7	7	X_7

Arbitrarily assign a rating of 100 points to the characteristic value with the highest subjective probability (e.g., X_1). Then, as in the first step, question the expert regarding the relative chance of occurrence of each of the other values on the ordinal scale in Table F-3 with respect to the value at the top of the scale. Assigning X_1 a rating of 100 points, the expert is first interrogated as to his feeling of the relative chance of occurrence of the second highest scale value (e.g., X_2), with respect to X_1. Does it have 25 percent chance? 60 percent? 70 percent? 80 percent? As much chance of realization as X_1? The relative probability rating, based on 100 points (i.e., 100 percent as much chance), will then be posted for X_2.

Next, question the expert about the relative chance of occurrence of the next highest scale (e.g., X_3) first with respect to the most preferred value (X_1), and then with respect to the second most preferred scale value (X_2). The resulting numerical ratings should concur. For example, if the expert decides that X_2 has 8/10 as much chance of occurring as does X_1, and that X_3 has 1/2 as much chance as X_1, and 5/8 as much chance as X_2, the ratings become X_1 = 100 points, X_2 = 80 points, and X_3 = 50 points. This process continues for each successively lower interval value on the ordinal scale as shown in Table F-3. Determine the relative number of points to be accorded each value with respect to the top scale and with respect to all other values on down the scale which are above the characteristic value in question.

In the event of minor disparities between relative probability ratings for a given value, the average of all such ratings for that characteristic value might be computed. For example, X_4 might be determined to be 3/10 as probable as X_1, 1/4 as probable as X_2, and 1/2 as probable as X_3. The three absolute ratings for X_4 are thus inferred to be 30, 20, and 25 points, respectively. The average of these ratings is 25. However, before averaging such figures, it might be beneficial to have the expert revaluate his relative ratings

2.4.3 Using the higher of the two previously specified scale values as a new basis, repeat 2.4.2 to determine the next value on the scale.

2.4.4 Repeat steps 2.4.2 and 2.4.3 until the high end point value of the range of parameters values is approached.

Employing this procedure, for the period required to successfully test a piece of equipment, may yield the results shown in Table F-1.

Table F-1 Characteristic Values for Equipment Test Durations

0_1	=	0 - 3 days
0_2	=	4 - 7 days
0_3	=	8 - 11 days
0_4	=	12 - 15 days
0_5	=	16 - 19 days
0_6	=	20 - 23 days
0_7	=	24 - 27 days

The descending order of probability or occurrence can be determined by applying the following paired comparison method. Ask the expert to compare, one at a time, the first interval value (0_1) of the set to each of the other values (0_2, 0_3, etc.), stating a preference for that value in each group of two values that he believes has the greater chance of occurring (denoting a greater probability of occurrence by >, an equal chance by =, and a lesser chance by <). The following hypothetical preference relationships could result for a set of seven values: ($0_1 < 0_2$, $0_1 < 0_3$, $0_1 < 0_4$, $0_1 < 0_5$, $0_1 < 0_6$, $0_1 < 0_7$).

Next, ask the expert to compare, one at a time, the second interval values (0_2) of the set to each of the other interval values succeeding it in the set (i.e., 0_3, 0_4, etc.). The following preference relationships might result: ($0_2 < 0_3$, $0_2 < 0_4$, $0_2 < 0_5$, $0_2 < 0_6$, $0_2 < 0_7$). Continue this process until all values (0_i) have been compared. Now total the number of times (0_i) value was preferred over other values. The results for this procedure are listed in Table F-2.

Table F-2 Summary of Preference Relationships

0_4	=	6 times
0_3	=	5 times
0_5	=	4 times
0_2	=	3 times
0_6	=	2 times
0_1	=	0 times
0_7	=	0 times

- lose $5,000, if cost is not between $15,100 and $20,000

Bet 1b - win $10,000 with probability of q
- lose $5,000 with probability of 1-q

The value of q is established initially, and the expert is asked which of the two bets he would take. The value of q is then varied systematically, either increased or decreased. The point at which the expert is indifferent between the two bets (with the associated q value) provides the probability of the cost being between $15,100 and $20,000. This process is repeated for each interval, and the results used create the PDF associated with the cost of that particular program event.

2.4 Modified Churchman/Ackoff Technique. Another method, which can be used to ascertain PDFs for cost, schedule, or performance parameters, is the modified Churchman-Ackoff method. This technique builds upon procedures which were presented by Churchman and Ackoff in 1954. This technique was developed as a means to order events in terms of likelihood. The modification to the technique was performed so that once the order of event likelihoods had been accomplished, relative probabilities could be assigned to the events and finally PDFs developed. So as to be relevant for our purposes, events are defined as range values for cost, schedule, or performance (activity durations) relating to the outcome of a specific activity in a program.

The modified Churchman-Ackoff technique is most appropriate when there is one expert, and that expert has a thorough understanding of the relative ranking of cost/schedule ranges and a limited understanding of probability concepts. Note that while the mathematical calculations appear to make this a very precise technique, it is still an approximation of an expert's judgment and should not be interpreted to be more exact than other similar techniques.

The first step in applying the modified Churchman-Ackoff technique is to define the relevant range of values. That is, the end points, along a range of values with zero probability of occurrence, must be specified. These values need only be any low and high values which the expert specifies as having zero probability of occurrence. Next, ranges of individual values within the relevant range must be determined. These ranges of values which will form the set of comparative values for this technique are specified by the following approach.

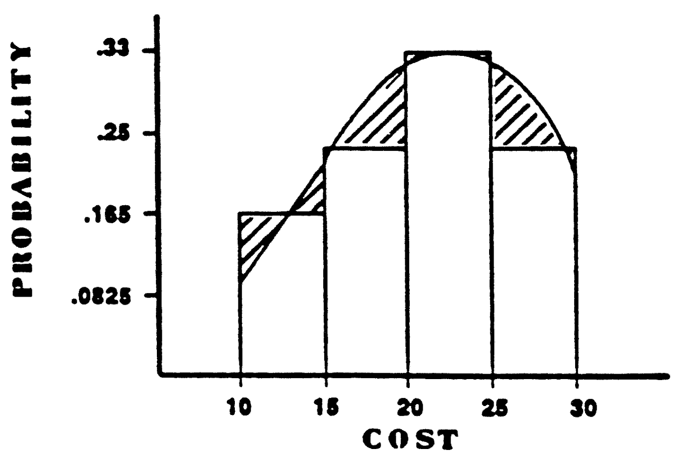
2.4.1 Start with the low value in the relevant range.

2.4.2 Progress upward on the scale of values until the expert is able to state a simple preference regarding the relative probabilities of occurrence of the two characteristic values. If he is able to say that he believes one value has either a greater chance or a lesser chance of occurring that the other of the two values, then it is inferred that the expert is able to discriminate between the two values.

$p \geq q$; likewise, if 1b is selected, $p \leq q$. By repeating the procedure, varying the value of q, the probability of event E can be ascertained. It is the point at which the expert is indifferent between bets 1a and 1b, where $p = q$. The degree of precision is dependent on the number of bets and the incremental changes of the value of q.

A way of avoiding the problem of a large number of bets to obtain p would be to assess the probabilities through the use of direct interrogation, and then to use the betting situation as a check on the assumed probabilities. To complete a PDF, the analyst repeats this procedure over a relevant range of interval values. The analyst then plots the points at the center of the range for each event and smoothes in a curve, so that the area under it equals one, as in Figure F-2. The analyst must ensure that all of the relevant axioms of probability are maintained.

Figure F-2 Fitting a Curve to Expert Judgment



Many people, when questioned one way, are likely to make probability statements that are inconsistent with what they will say when questioned in another equivalent way, especially when they are asked for direct assignment of probabilities. As the number of events increases, so does the difficulty of assigning direct probabilities. Therefore, when this is a problem, the betting method is most appropriate.

To apply the betting technique, we will select one interval for the relevant range to demonstrate how this method can be used to obtain probability estimates and, hence, PDFs. The bet is established as follows:

Bet 1a - win $10,000, if cost is between $15,100 and $20,000 complex, resource intensive methods.

The application of the direct method is quite simple. The analyst would define a relevant range and discrete intervals for the parameter for which the PDF is to be constructed. For example, the analyst might define the relevant time duration for a program activity (test of a piece of equipment) to be between 0 and 27 days. The analyst would then break this relevant range down into intervals, say intervals of three days, the resulting formulation would look as follows:

0 - 3 days	16 - 19 days
4 - 7 days	20 - 23 days
8 - 11 days	24 - 27 days
12 - 15 days	

Given these intervals over the relevant range, the analyst would then query the expert to assign relative probabilities to each range. From this, the form of the PDF could be identified. It is imperative that the axioms of probability not be violated.

Besides the application already described, the analyst could request the expert to provide a lowest possible value, a most likely value, and a highest possible value. The analyst then makes an assumption about the form of the density function. That is, is the PDF uniform, normal, beta, or triangular?

2.3 Betting. One method of phrasing questions to experts in order to obtain probabilities for ranges of values (cost/schedule) states the problem in terms of betting. A form of this method helps the expert (assessor) assess probabilities of events which are in accordance with his judgment. The assumption with this method is that the judgment of the expert may be fully represented by a probability distribution, $f(x)$ of a random variable x. This method offers the expert a series of bets.

Under ideal circumstances, the bets are actual, not hypothetical. That is, in each case the winner of the bet is determined and the amount of money involved actually changes hands. However, under our circumstances, this is not feasible (or legal!). In each case, the expert must choose between two bets (the expert is not allowed to refrain from betting). The expert must choose between a bet with a fixed probability q of winning and $1-q$ of losing, and a bet dependent on whether or not some event E (a particular program activity duration range, or cost range) occurs. The bet can be depicted as follows:

Bet 1a - win \$A, if the event E occurs
- lose \$B, if event E does not occur

Bet 1b - win \$A with probability of q
- lose \$B with probability of 1-q.

The expected values of bets 1a and 1b to the expert are respectively $Ap + Bp - B$ and $Aq + Bq - B$, where P is the probability of event E occurring. The following inferences may be drawn from the experts decision: if bet 1a is chosen, $Ap + Bp - B \geq Aq + Bq - B$, so

Using Figure F-1, the random variable x might represent a hardware system cost; the probability of the system costing $10,000 would be 0.13.

There are a number of methods which can be used to convert qualitative judgment into quantitative probability distributions. The remainder of this section will focus on a few of the most popular, practical, and accurate techniques for doing so. The techniques discussed were selected because they are relatively simple and easy to master. This factor is of paramount importance, because in most cases the analyst who will be performing this task will have neither the time nor the knowledge of the advanced probability concepts required to perform more complex techniques. Those interested in more exotic, complex techniques are referred to Appendix B, Bibliography. The following techniques will be discussed in this Appendix:

- Diagrammatic
- Direct
- Betting
- Modified Churchman/Ackoff technique
- Delphi Approach.

2. Description of techniques

2.1 Diagrammatic. Many analysts prefer the diagrammatic method as a way of capturing and representing an expert's judgment. This method is a simple way of describing an expert's uncertainty by presenting him with a range of PDF diagrams and having the expert select the shape of the PDF which is considered to reflect most accurately the schedule, cost, or technical parameter in question. Using this method, the analyst can ascertain whether the PDF is symmetric or skewed, the degree of variability, etc. For example, if the expert feels that there is a great amount of risk associated with completing an activity within a certain period of time, a PDF skewed to the right may be selected. Likewise, activities with little risk may be skewed to the left. If the expert feels that each value over a given range is equally likely to occur, a uniform distribution may be most appropriate. The analyst and the expert, working together, can select the PDF which most accurately reflects the schedule, cost, or technical item under question.

The diagrammatic method of obtaining PDFs is applicable when the expert has a sound understanding of probability concepts and can merge that understanding with his understanding of the parameters under question. In this way, the expert can accurately identify the appropriate PDFs.

2.2 Direct. The direct method is a relatively simple technique which can be used to obtain subjective probability distributions by asking the expert to assign probabilities to a given range of values. The direct method of obtaining PDFs is applicable: (1) When questions can be phrased to the respondents in such a way that there is no confusion likely to exist in the respondent's mind, and (2) When the results will not violate the axioms of probability. This method is applicable when time/resource constraints do not allow for more

QUANTIFYING RISK JUDGMENT

1. General. All risk assessment techniques share a common need, and that is the acquisition of expert judgment as input to any of the risk assessment models. Inherent in judgment is a degree of uncertainty. When acquiring quantifiable expressions of judgment, it is imperative that the axioms of probability not be violated:

1.1 The probabilities of all possible events must sum to one.

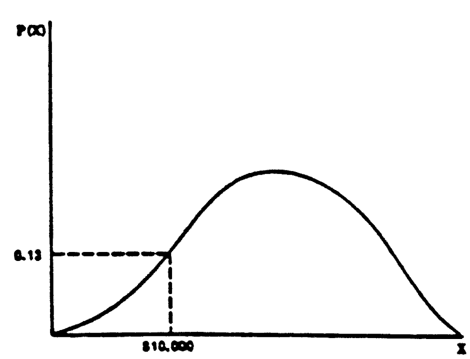
1.2 The probability of any event P(A) must be a number greater than or equal to zero, and less than or equal to one ($0 \leq P(A) \leq 1$).

1.3 The probability of joint events is the product of the probability that one event occurs and the probability that another event occurs, given that the first event has occurred ($P(A) \times P(B|A)$. Under these circumstances, the events are termed dependent.

1.4 When the probability of joint events occurring is simply the product of the probabilities of each, $P(A) \times P(B)$, the events are said to be independent. That is, the two events have nothing in common or can occur simultaneously.

The challenge for the analyst is to obtain expert judgment in the areas of cost, schedule and technical performance, which is qualitative by nature. Next, he/she must convert it to a quantitative form, so that the results can be depicted in the form of a probability density function (PDF), which serves as input to the various risk models (keep in mind that this is only necessary when a quantitative model has been selected). A probability density function is a smooth line or curve such as shown in Figure F-1. A PDF of a random variable x is a listing of the various values of x with a corresponding probability associated with each value of the random variable x. For our purposes, x would be a cost, schedule, or performance value. Note the total area under the curve equals 1.

Figure F-1 Probability Density Function



APPENDIX F

QUANTIFYING EXPERT JUDGMENT

pler, and more manageable segments. Many similarities exist between decision tree analysis and more complicated forms of management and risk analysis, such as the Program Evaluation and Review Technique (PERT) and the Critical Path Method (CPM). All three forms of analysis presume that a sequence of events can be broken down into smaller and smaller segments, therefore more accurately representing reality.

Decision tree analysis helps the analyst break a problem down into various sectors or branches in order to simplify potential decision-making. As an example, suppose that a widget is being manufactured in the following fashion. Either machine A or machine B can be used for the first step (of a two-step manufacturing process) with equal probability of 0.5. Then the second step has machine C or D processing the widget. Machine C is used 70 percent of the time if the widget was first processed with machine A, and used 40 percent of the time if the widget was first processed with machine B. Otherwise, machine D is used for the second step. Decision tree analysis can be used to help compute the probability of the widget being produced by the various combinations of machines (AC,AD,BC,BD). Figure E-7 illustrates the decision tree and the expected probability for each of the four manufacturing process alternatives.

Note that an alternative's probability is merely the product of the individual processes making up that alternative, since the individual processes are independent of each other. Note also that the sum of the probabilities for all of the four processing alternatives is 1.00.

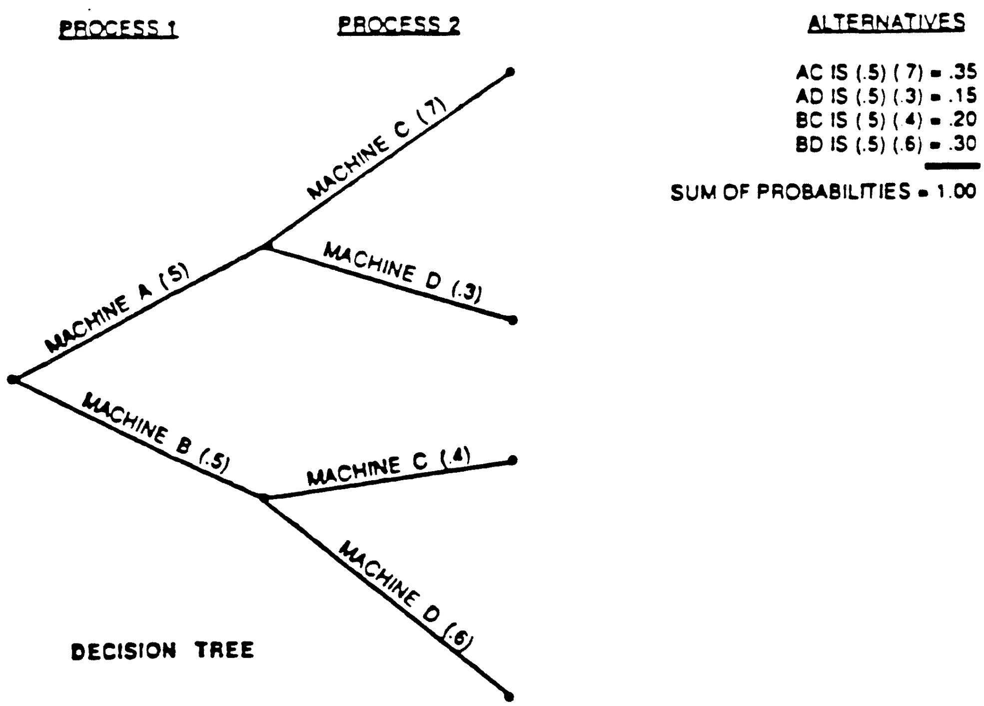


Figure E-7 Decision Tree

Independence, Expected Value, and Decision Tree Analysis

Statistical independence is an important concept upon which a good deal of methodologies are based. For this appendix it is important to give a brief definition before going through the basic principles of expected value and decision tree analysis.

Most discussions of statistical independence begin with a tutorial on conditional probability, sample space, and event relationships. Rather than discuss these concepts, a more intuitive (practical) definition of statistical independence is that two events are said to be independent if the occurrence of one is not related to the occurrence of the other. If events are occurring at random, then they are independent. If events a: e not occurring at random, then they are not independent. A set or group of possible events are said to be mutually exclusive and collectively exhaustive if they are all independent, and the sum of their probabilities of occurrence is 1.0. This is the basic notion behind expected value.

To illustrate the expected value concept, suppose that a game of chance can be played for $1.00. It is a very simple game. The bettor pays $1.00 and has a chance to win $50.00. The bettor may also win $2.00 or no money at all. The dollar amounts and probability of winning are shown by Table E-1.

Table E-1 Expected Values Example

AMOUNT VALUE	PROBABILITY OF WINNING	EXPECTED VALUE
$50.00	0.01	0.50
2.00	0.10	0.20
0.00	0.89	0.00
TOTAL	1.00	$0.70

The bettor would like to know, before actually paying his dollar, what the expected winnings are. The expected value of winnings is the sum of the winning amounts multiplied by their respective probability of occurrence or

($50.00) (0.01) + ($2.00) (0.10) + ($0.00) (0.89) = $0.50 + $0.20 + $0.00 = $0.70.

Since the bettor can only expect winnings on the average of seventy cents and pays one dollar to play the game, the net payoff is a negative thirty cents.

One might believe that most individuals, when forced to face this logic, would choose not to play. However this is a very realistic example of gambling and risk. Many individuals would play this game. They are willing to accept the risk of losing $1.00 in order to take a chance at winning $50.00. They are risk-prone. The individual who follows the basic logic of this example and does not play is said to be risk-averse.

Expected value is a notion prerequisite to the following discussion on Decision Tree Analysis. Decision tree analysis attempts to break down a series of events into smaller, sim-

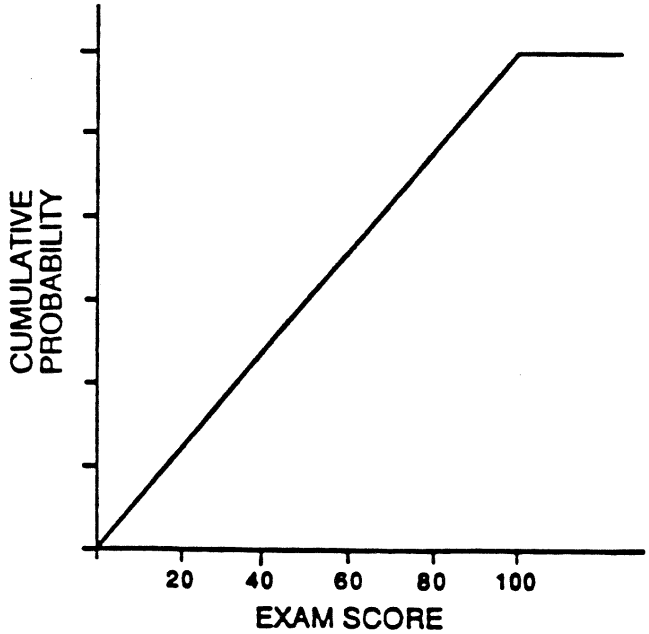


Figure E-5 CDF of a Uniform Distribution

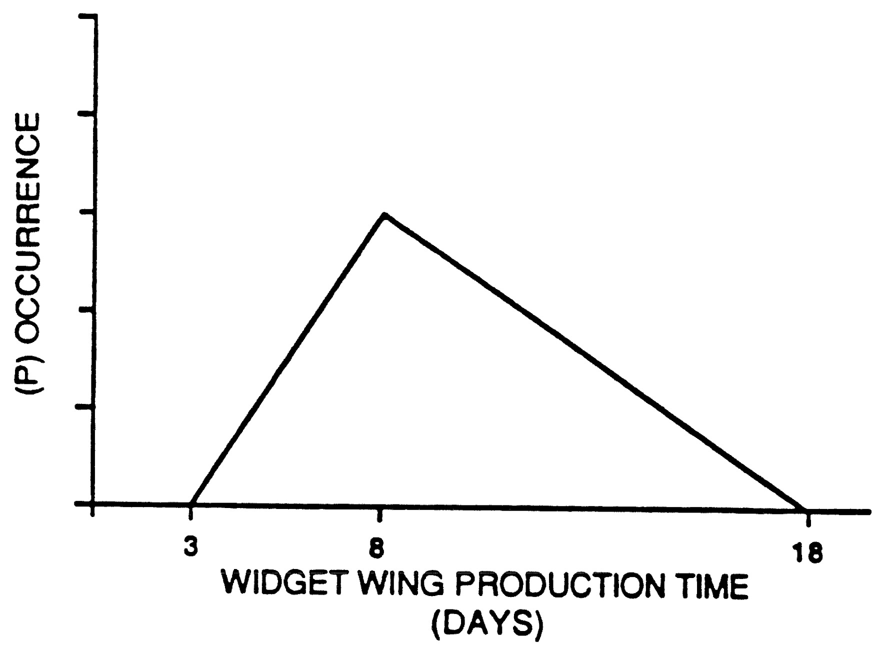


Figure E-6 PDF of a Triangular Distribution

ample shown by Figure E-6, one notices that eight days is the most likely production time for a widget wing. Clearly the average is "to the right" and is very close to 9.3 days. Hence, the triangular distribution, when skewed, has a mode and mean which are clearly different. Contrast this to the normal distribution, where the mode and mean are the same (as is the median).

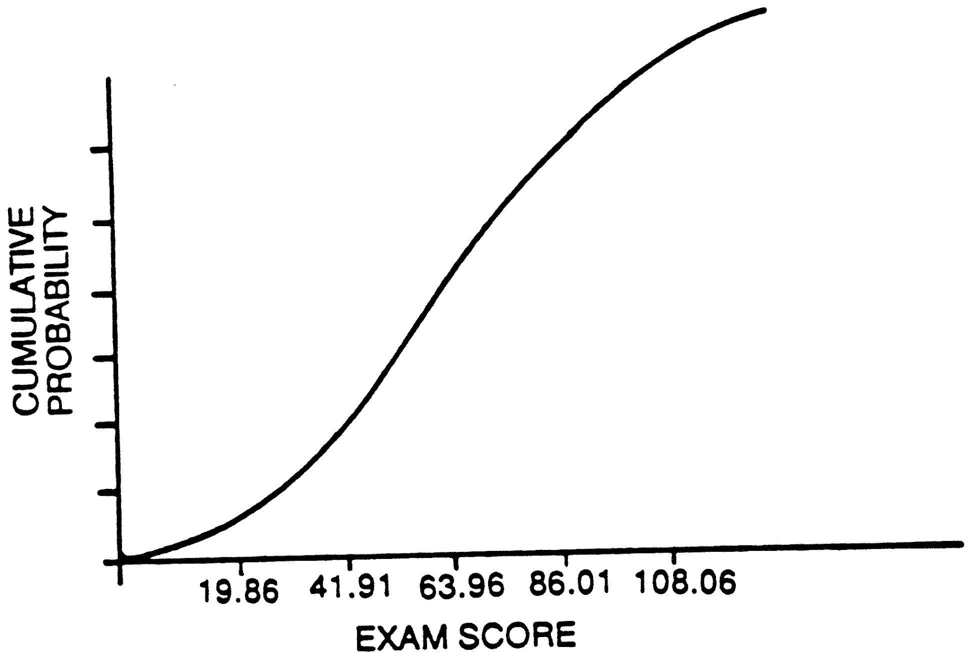


Figure E-3 CDF of a Normal Distribution

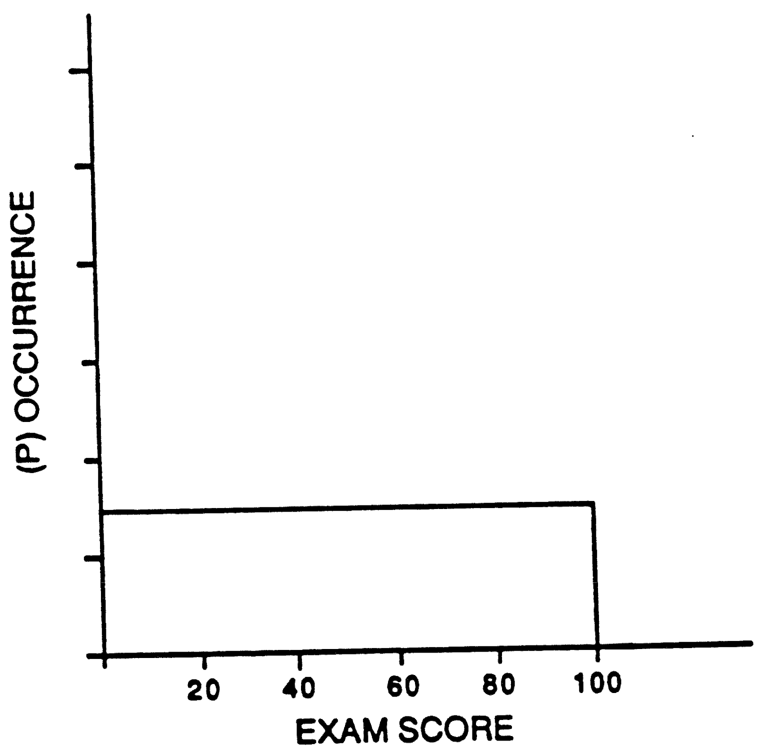


Figure E-4 PDF of a Uniform Distribution

by Figure E-6, is not necessarily symmetric. Indeed, many times the triangular distribution is purposely nonsymmetric or "skewed to the right" to reflect the possibility of very long time durations. These long durations are less likely to occur but do happen occasionally. In the exlems associated with risk are the Normal, Uniform, Triangular, and Beta. Discussion of the Beta distribution is beyond the scope of this appendix. If the reader requires further information on the Beta distribution, any of several statistics and operations research books readily available can supply the information.

For the normal distribution, 68.3 percent of all possible values lie within one standard deviation of the mean, 95.4 percent lie within two standard deviations, and 99.7 percent lie within three standard deviations. To pictorially show the above, one can look at the Probability Density Function (PDF). The PDF gives the probability that certain values will occur. Figure E-2 below is a PDF for the exam scores example, assuming that the scores are from a normal distribution.

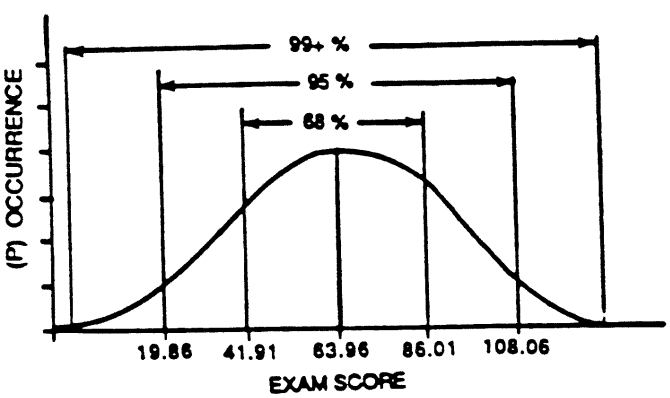


Figure E-2 PDF of a Normal Distribution

The normal distribution is, by strict definition, a continuous distribution. However, Figure E-2 implies that fractional exam scores are possible, but of course it is not realistic in this example. A discussion of the differences between discrete and continuous distribution is beyond this appendix, and since the example is only meant to be used for illustrative purposes, this finer point of statistics will be ignored. Figure E-2 also implies that extra credit is given since scores exceeding 100 are possible, and this could certainly be within the realm of our example. The most important distinction of the normal distributions PDF is the bell shape of the curve. This is the most definitive characteristic of any PDF: shape.

The Cumulative Density Function (CDF) is arithmetically the summation of the PDF. In plainer words, the CDF gives the probability a value (or any value less than the value) will occur. The shape of the various distributions CDFs are distinctive, and the CDF is merely another way of illustrating the distribution. Figure E-3 is a typical CDF for normally distributed values, in this case the exam scores example.

The uniform distribution is used to describe a set of values where every value has an equal probability of occurrence. Returning once again to the exam scores example, one might hypothesize that all possible scores (1, 2, 3, ... 98, 99, 100, ...) have an equal probability of occurrence: 0.01. The PDF for this is illustrated by Figure E-4.

Figure. E-5 illustrates the uniform CDF.

The triangular distribution is often used in risk analysis situations to describe the most optimistic, most likely, and most pessimistic durations of some event or activity. The PDF of the triangular distribution, illustrated

$$\text{VARIANCE} = \frac{\sum_{i=1}^{n} X_i^2 - \frac{\left(\sum_{i=1}^{n} X_i\right)^2}{n}}{n-1}$$

For this example the variance is:

$$\frac{132275 - \frac{(1855)}{29}}{28} = 486.4$$

The standard deviation is the square root of the variance. The standard deviation has a more intuitive appeal than does the variance since the standard deviation is mathematically the average variation of a value from the mean. For this example the standard deviation is $\sqrt{486.4} = 22.05$. The range is the high score minus the low score. For this example, the range is 100–10=90.

Many times when examining data a "level of confidence" or "confidence interval" is used to indicate what certainty or faith is to be put in the sample that is being taken as representative of the entire population. Far and away the most common measure in the area is the confidence interval for the mean. A statement such as follows is made about a particular sample mean:

"The 95 percent confidence interval for the mean is 56 to 72."

This statement means statistically that of all the possible samples of this size taken out of this population, 95 percent of the samples will have a mean between 56 and 72. It does not mean that 95 percent of all the possible values that are sampled will fall between 56 and 72, which is the common, though faulty, interpretation of the statements.

Confidence intervals are determined by adding and subtracting some calculated value from the mean of the sample. Usually, but not always, this value is based on the standard deviation of the sample. As an example, if the population from which a sample is taken is determined to be normally distributed, and we have assumed this in the previous statements (this determination may be made based on the relative values of the mean, variance and standard deviation, mode, median, range, and other factors), then a 95 percent confidence interval for the population is calculated in this manner:

$$\bar{X} \pm 1.96\ \sigma$$

where $\bar{X}$ is the sample mean and σ is the standard deviation. A 95 percent confidence interval for the mean is calculated in this manner:

$$\bar{X} \pm 1.96 \frac{\sigma}{\sqrt{n}}$$

where $\frac{\sigma}{\sqrt{n}}$ is commonly referred to as the standard error.

One might ask how the population is determined to be normal (or normally distributed) in the first place. Similar groups of numbers have similar relationships between their respective parameters. These similarities help determine which distribution describes the entire population. Typical distributions for prob-possible outcomes result in a "10". The odds against throwing a "10" are "11 to 1." This is since the total number of possible non-10 outcomes, thirty-three, is eleven times the number of outcomes, three, which result in a "10".

Probability is a key quantitative measure associated with many risk assessment techniques. The above examples are simplistic but show how easy it is to comprehend probability concepts. The next two sections expand on the basic premise of probability understanding.

Descriptive Statistics, Confidence, and Distributions

Any group of numbers, such as a sample composed of quantitative evaluations, may be described with the following basic statistical parameters:

- mean
- median
- range
- mode
- variance and standard deviation

These parameters enable the statistician to determine what level of confidence (or assurance) may be accorded to predictive statements about the entire population of numbers. The parameters also help determine of what possible statistical distribution the sample is a part. Conversely, a statistical distribution may be described by such parameters. A statistical distribution is basically just a way to describe which numbers will appear more often (or with a high probability), and which numbers will appear less often (or with a low probability). The following paragraphs define the parameters in some detail and then discuss confidence levels, PDFs and CDFs, and the other relevant distributions applied in risk analysis.

For illustrative purposes let the following numbers represent exam scores for a fictitious introductory statistics course:

75	60	100	65
80	45	25	45
60	90	60	40
50	70	55	10
95	70	85	20
70	65	90	90
65	80	70	55
70			

Let x_i represent these numbers, where i is indexed from 1 to 29. So $X1 = 75, X2 = 80, X3 = 60, ..., X28 = 90, X29 = 55$. The mean of these numbers is nothing more than the arithmetic average. The mean is computed thus:

$$\text{MEAN} = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{1855}{29} = 63.96$$

where n is the number of exam scores. The mode, the most likely or probable score, is 70. The mode occurred five times more often than any other score. The median is the middle score if the scores are ranked top to bottom. Since there are twenty-nine scores altogether, the median is the fifteenth score, which is a 65. The variance and standard deviation of a group of numbers are an attempt to describe the dispersion or scattering of the numbers around the mean. The variance is computed using the following formula:

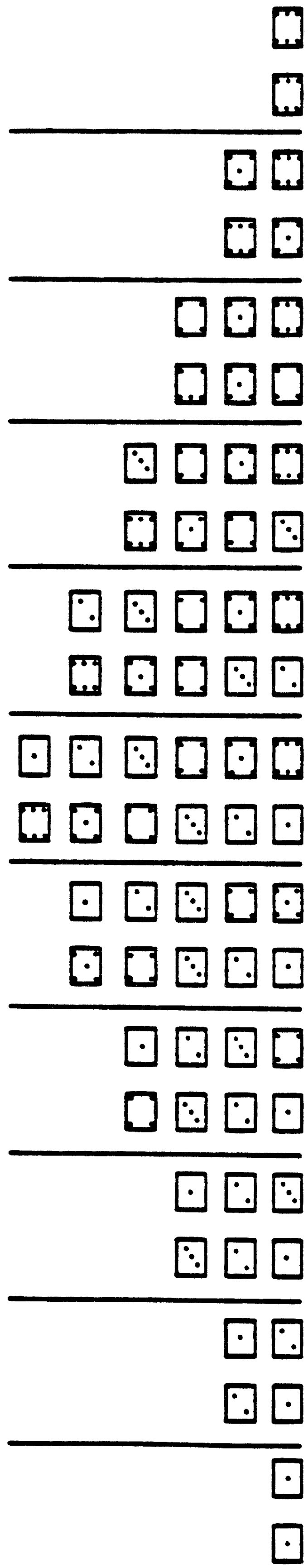


Figure E-1 Dice Throwing Results - Variance

1. INTRODUCTION

This appendix serves as a very basic introduction to probability and statistical concepts that may be useful for risk analysis. The appendix is by no means all inclusive but rather may be thought of as a primer. The appendix is divided into three sections. The first section is an introduction to probability centering on definitions and simple examples. The second section begins with a summary of descriptive statistics including a look at statistical confidence and confidence intervals. The second section then gives an explanation of probability density functions (PDFs) and cumulative density functions (CDFs), which define distributions such as the Uniform, Normal, and Triangular which are relevant to risk analysis. The third section discusses statistical independence, which is the prerequisite for the concept of expected values. Decision tree analysis is illustrated to show the merit of the expected values approach.

Probability

Probability is a concept used by many people everyday. As an example the weatherman predicts a 30 percent probability of rain. This means that in the long run one might expect rain 30 days out of 100 when conditions are the same as they are at the time the forecast is made. For risk analysis a statement might be made to the effect that the developmental stage of weapon system A has a 10 percent probability of a schedule (time) overrun. This is equivalent to saying that of all the developmental stages of weapon systems similar to A, in the past 10 percent have had a schedule overrun.

More formal definitions of probability are given below.

PROBABILITY - "1. The quality or condition of being probable; likelihood. 2. A probable situation, condition, or event. 3. Math. A number expressing the likelihood of occurrence of a specific event, such as the ratio of the number of experimental results that would produce the event to the total number of results considered possible." (*The American Heritage Dictionary*).

PROBABILITY - "In practical situations, probability is used as a vehicle in drawing inferences about unknown population characteristics. Additionally, ..., probability concepts can be used to give us an indication of how good these inferences are," (*Statistical Methods for Business and Economics*) Pffenberger and Patterson, 1977. Reference 1.

Many individuals think of probability in relation to gambling and games of chance such as card playing and dice throwing. They measure the probability of an event in terms of the odds against the event happening. One further example, the throwing of a pair of dice, will illustrate the inverse relationship between probability and "the odds against an event." Throwing an ordinary pair of dice results in one of thirty-six possible outcomes. These are illustrated by Figure E-1.

The probability of throwing a "10" is 3/36 or 0.083. This is three out of the thirty-six

APPENDIX E

BASIC PROBABILITY CONCEPTS

values where every value has an equal probability of occurrence.

Utility Theory - Theory of preference under conditions of risk.

Variance - A measure of the variability of a random variable. The standard deviation squared. Often symbolized as Var ( ).

Work Breakdown Structure - A product oriented family tree division of hardware, software, services, and other work tasks which organizes, defines, and graphically displays the product to be produced, as well as the work to be accomplished to achieve the specified product.

occurrences. It allows for (1) eliminating risk wherever possible; (2) isolating and minimizing risk; (3) developing alternate courses of action; and, (4) establishing time and money reserves to cover risks that can be avoided.

Risk Rating Scheme - A method of assigning a risk level such as high, medium, or low risk based on an agreed value assigned to the probability of occurrence and the severity of the impact of failure.

Risk Transfer - The sharing of risk through contractual agreements such as performance incentives, warranties, etc. It can also be between Government agencies as in multi-service programs.

Schedule Risk - The risk to a program is not meeting the major milestones.

Simulation - The operation of a model which provides outputs analogous to the system modeled.

Skew - The asymmetry of a probability density function. The skew is to the side of the mode under which lies the greatest area.

Skewness - The measure of the amount of skew.

Slack - The difference between the earliest possible completion time of a path or activity and its latest possible completion time.

Standard Deviation - The square root of the variance. Often used because it is in the same units as the random variable itself, and can be depicted on the same axes as the Probability Density Function of which it is a characteristic.

Standard Normal Function - A probability function centered on zero, with a standard deviation of 1, having a bell shape and covering values that become negatively and positively infinite.

Subjective Probability - An expression of predictability in terms of personal statements obeying the axioms of probability and equal to the probabilities acceptable to the assessor for a substitute gamble.

Supportability Risk - The risks associated with fielding and maintaining systems which are currently being developed or have been developed and are being deployed.

SEMP - Systems Engineering Management Plan. The plan for the system engineering aspects of a program.

Technical Risk - The risk associated with evolving a new design to provide a greater level of performance than previously demonstrated. Includes the same or lesser level of performance subject to new constraints such as size or weights.

TEMP - *T*est and *E*valuation *M*aster *P*lan. The plan for all required testing and evaluation of a system.

Uncertainty - The condition of having outcomes with unknown probabilities of occurrence.

Uniform Distribution - A set of

VN. If data shows the expression to be inexact, regression analysis finds values of F and V which give the value, C, closest to those associated with all data values of N. Regression Analysis is a process by which the relationship between paired variables can be described mathematically using the tendency of jointly correlated random variables to approach their mean.

Risk - The condition of having outcomes with known probabilities of occurrence, not certainty of occurrence.

Risk - The combination of the probability of an event occurring and the significance of the consequence of the event occurring.

Risk Analysis - Involves an examination of the change in consequences caused by changes in the risk-input variables.

Risk Assessment - The process of examining all aspects of a program with the goal of identifying areas of risk and the corresponding potential impact.

Risk Assumption - A conscious decision to accept the consequences of the risk occurring.

Risk Avoidance - Risk avoidance is to non-select an option because of potentially unfavorable results. Selection of an option because of lower risk is also risk avoidance.

Risk Control - Risk control is the process of continually monitoring and correcting the condition of the program.

Risk Drivers - The technical, programmatic, and supportability risk facets.

Risk Handling - The last critical element in the risk management process. It is the action or inaction taken to address the risk assessment and risk analysis efforts.

Risk Identification - Narrative statements describing the program risks.

Risk Avoidance - Risk avoidance is to non-select an option because of potentially unfavorable results. Selection of an option because of lower risk is also risk avoidance.

Risk Control - Risk control is the process of continually monitoring and correcting the condition of the program.

Risk Drivers - The technical, programmatic, and supportability risk facets.

Risk Handling - The last critical element in the risk management process. It is the action or inaction taken to address the risk issues identified and evaluated in the risk assessment and risk analysis efforts.

Risk Identification - Narrative statements describing the program risks.

Risk Management - Relates to the various processes used to manage risk.

Risk Planning - Forcing organized purposeful thought to the subject of eliminating, minimizing, or containing the effects of undesirable

Parametric Cost Estimating - Cost estimating by means of obtaining information from a data bank by specific parameters such as weight, size, material composition, etc.

Path - A sequence of arcs.

Percentile - The value of an uncertain quantity, generally referred to as an "*n*th percentile", which is greater than or equal to *n* percent of all values.

PERT - Program Evaluation and Review Technique. An early network analysis technique for acquisition programs, in which each activity duration was characterized by its mean or expected values and no uncertainties were incorporated.

Probabilistic Event Analysis - Risk assessment, using a variation of the decision analysis method, developed in reference (54) of Appendix B, Bibliography, Basic Discussion.

Probability Density Function (PDF) - A probability expression such that the area under the function between defined limits of the values on which it is defined represents the probability of the values within those limits.

Probability Function - A mathematical expression, defined for an uncertain quantity, associating a probability with each value or non-redundant combination of values in the set.

Probability Mass Function (PMF) - A function assigning probabilities to each value of uncertain quantity having only discrete or discontinuous values.

Program Advocacy - The personal interest in the program under study to the exclusion of other programs usually without merit.

Program Management Directive (PMD) - A document containing the goals of the program, usually set up as requirements such as cruising speed, dash capability, etc.

Program Management Plan (PMP) - The program plan from feasibility to phase out of the system.

Program Risk - The probability of not achieving a defined cost, schedule, or technical performance goal.

Programmatic Risk - The risks involved in obtaining and using applicable resources and activities that are outside of the programs control, but can affect the program's direction.

Random Number Generator - A computer program capable of providing numbers able to pass statistical tests indicating that any number between the limits of those generated is equally as likely to be generated.

Regression Analysis - Determination of the values of constants in a mathematical expression which gives results that are the closest to the observed values associated with values of the data used in the expression. For example, if cost C is assumed to be the sum of a fixed cost, F, and variable cost, V, for N items, C = F +

and Contractors) incurred during the projected life of the system, subsystem, or component. It includes total cost of ownership over the system life cycle including all research, development, test and evaluation, initial investment, production, and operating and support (Maintenance) cost.

Management Reserve - An amount of budget held aside from direct allocation to program elements as a reserve for contingencies.

Manufacturing Plan - The plan that contains the details of how the system is to be manufactured. Includes the make or buy list of the equipment.

Mode - A point on a probability density function where the probability goes from increasing to decreasing, that is, a maximum.

Model - A partial description of a system using sufficient detail for some analytic or descriptive purpose.

Modified Churchman - Ackoff Method - A means of ordering events in terms of likelihood to occur.

Moment - A function (called the expectation) of a probability law, often referred to as an "nth moment", where n is any number and denotes an exponent on the uncertain quantity. For example, if x is a discrete uncertain quantity, the third moment is the sum of all values of x^3 times the probability of each respective value of x.

Monte Carlo - The simulation technique in which outcomes of events are determined by selecting random numbers subject to a defined probability law. If the random number falls within the limits of an outcome's probability, that outcome is chosen.

Multiplicative Cost Elements - Cost elements whose value is derived by a multiplication of other cost elements.

Network - A collection of points connected by lines.

Network Based Schedule - An objective oriented plan of action that includes all important activities and events.

Network Program Model - Representation of a program by means of a network in which the points (nodes) stand for program decision points or milestones and the lines (arcs) stand for program activities which extend over time and consume resources. Nodes may be regarded as activities requiring no time to complete.

Node - One of a collection of points defining a network.

Normalized Geometric Mean Vector Method - A technique devised to determine the assignment of individual event probabilities and fulfill the axioms of probabilities.

Objective Probability - Probability which can be inferred from objective facts.

Odds - The ratio of probabilities of occurrence and non-occurrence; e.g., for a throw of a fair die the probability of a four is 1/6. The odds are 5 to 1.

is that of the occurrence of a value less than or equal to a given value.

Decision Analysis - Examination of decision problems by analysis of the outcomes of decision alternatives, the probabilities or arrival at those outcomes, and the intervening decisions between selection of alternatives and arrival of outcomes. The attributes of the outcomes are examined and numerically matched against preference criteria.

Decision Tree - Representation of a decision problem as paths from a present decision through alternative, intermediate decisions and risky events to outcomes. The representation is similar to an increasingly branched tree.

Deterministic - A term generally used to refer to a single iteration of a risk network that has constants reflecting "most likely" values as input parameters. As opposed to "Probabilistic" which has distributions as input parameters that may be sampled many times.

Delphi Technique - The use of a group of knowledgeable individuals to arrive at an estimate of an uncertain situation.

Programmatic Method - A way of describing an expert's uncertainty by presenting a range of PDF diagrams with a selected general shape.

Engineering Change Order Allowance - A budget category to be used for funding changes in the physical or performance characteristics of a system.

Expected Value - The probabilistic average of an uncertain quantity. It equals the sum of all the products of each considered value times its corresponding probability. Also called the mean when applied to all possible values of the uncertain quantity.

Gantt Chart - A bar graph of horizontal bars showing program element commencement and completion against time.

Histogram - A vertical bar chart. A method often used to represent a Probability Mass Function (PMF).

Incentive Share Ratio - The ration of government-to-contractor assumption of cost or savings related to contract target cost.

Independence (also statistical independence) - The relationship between two or more events when knowledge of the probability of occurrence of one does not alter the probability of another.

ILSP - Integrated Logistics Support Plan: The plan that defines the method to be used in supporting the system once it is deployed.

Judgment Matrix - A square array of values such that all entries are positive for every entry in row i and column j there is an entry in row j and column i which is the reciprocal of the first.

Life Cycle Cost (LCC) - An approach to costing that considers all costs (Government

Acquisition Environment - The totality of policies, practices and practical considerations relative to management of acquisition programs.

Acquisition Plan - Encompasses program objectives, direction, and control through the integration of strategic, technical, and resource concerns. Ideally, the acquisition strategy is structured at the outset of the program to provide an organized and consistent approach to meeting program objectives within known constraints.

Activity - A program element consuming time and resources. It can be zero if it is a constraint.

Arc - The line connecting two points in a network.

Coefficient of Variation - Ratio of standard deviation to expected value. (See Standard Deviation and Expected Value). A measure of relative uncertainty.

Confidence Interval - Limits of an uncertain quantity (like cost) between which there is a given probability of occurrence, Expressed as in "the *n* percent confidence interval". The confidence level is the left hand lower confidence interval, so that one may say, "C is the *n*th confidence level," meaning there is an *n* percent probability of cost being between 0 and C.

Confidence Level - Percentile.

Consistent Judgment Matrix - A judgment matrix that expresses relationships like probabilities, so that if probability of I is m times that of J, and J is n times that of K, then the probability of I is mn times that of K. Since each entry is a ratio, r_{ij}, of the probability of I divided by the probability of J, then r_{ij} times r_{jk} equals r_{ik}.

Constraint - An activity that does not consume time or resources. It acts as a connector between milestones or events.

CER - Cost Estimating Relationship. An estimating relationship in which cost of a system is the mathematical result of a formula having selected system measurements (like thrust or weight) as values in the formula.

Cost Risk - The risk to a program in terms of overrunning the program cost.

Critical Index - The number of times each activity appears on the critical path during simulation.

Critical Path - A path with no slack or float.

CPM - Critical Path Method similar to PERT, but activity oriented with single time estimates.

Cumulative Distribution Function - A curve or mathematical

expression which associates a probability to all values in the set of values over which it is defined, so that the probability

RAA - Required Assets Availability

RFP - Request for Proposals

R&M - Reliability and Maintainability

RMP - Risk Management Plan

RMPP - Risk Management Program Plan

SCRAM - Schedule Risk Assessment Module

SEMP - Systems Engineering Management Plan

SERP - Support Equipment Recommendation Document

SOW - Statement of Work

SPD - System Program Directive

STE - Support and Test Equipment

S/W - Software

TAAF - Test, Analyze and Fix

TBD - To Be Determined

TEMP - Test and Evaluation Master Plan

TO - Technical Order

TSARC - Transportation Systems Acquisition Review Council

USAF - U.S. Air Force

WBS - Work Breakdown Structure

FAA - Federal Aviation Administration

FCA - Functional Configuration Audit

FSD - Full Scale Development

G&A - General and Administrative

GAO - Government Accounting Office

GFE - Government-Furnished Equipment

GFI - Government-Furnished Information

GFP - Government-Furnished Property

H/W - Hardware

HOL - High Order Language

ICA - Independent Cost Estimate

ILS - Integrated Logistics Support

ILSP - Integrated Logistics Support Plan

IMIP - Industrial Modernization Incentives Program

IO - Input/Output

IOC - Initial Operational Capability

IOT&E - Independent Operational Test and Evaluation

KDSI - Thousands of Delivered Source Instructions

LCC - Life Cycle Cost

LOR - Level of Repair

LRIP - Low Rate Initial Production

LRU - Lowest Repairable Unit

LSA - Logistics Support Analysis

LSAR - Logistics Support Analysis Report

MP - Manufacturing Plan

M/S - Milestone

NAS - National Airspace System

OJT - On-the-Job-Training

O&M - Operations and Maintenance

O&S - Operations and Support

OSD - Office of the Secretary of Defense

P_3I - Pre-Planned Product Improvement

PCA - Physical Configuration Audit

PCS - Physical Control Space

PDF - Probability Density Function

PDG - Procurement Document Generator

PDM - Precedence Diagramming Method

PDR - Preliminary Design Review

PERT - Program Evaluation and Review Technique

PMD - Program Management Directive

PMO - Program Management Office

PMP - Program Management Plan

PPS - Post Production support

QA - Quality Assurance

APPENDIX D

ACRONYMS

ADM - Arrow Diagram Method

AFMC - Air Force Material Command

AFSC - Air Force Systems Command

AP - Acquisition Plan

ARMG - Acquisition Risk Management Guide

ARMP - Acquisition Risk Management Plan

ATE - Automatic Test Equipment

BIT - Built-In Test

BITE - Built-In Test Equipment

CAD - Computer Aided Design

CAM - Computer Aided Manufacturing

CASA - Cost Analysis Strategy Assessment

CDF - Cumulative Density Function

CDR - Critical Design Review

CDRL - Contract Data Requirements Data List

CER - Cost Estimating Relationship

CE - Concept Exploration

CI - Configuration Item

CIP - Capital Investment Plan

CLS - Contractor Logistics Support

CPR - Cost Performance Report

COTS - Commercial-Off-The-Shelf

CPM - Critical Path Method

CSCI - Computer Software Configuration Item

CSNAS - Computer Support Network Analysis Technique

CWBS - Contractor Work Breakdown Structure

DEM/VAL - Demonstration/ Validation

DoD - Department of Defense

DoE - Department of Energy

DoT - Department of Transportation

DSMC - Defense Systems Management College

DT&E - Developmental Test and Evaluation

ECO - Engineering Change Order

ECP - Engineering Change Proposal

EMD - Engineering and Manufacturing Development

EMV - Expected Monetary Value

EPA - Environmental Protection Agency

ESD - Electronic Systems Division

APPENDIX D

ACRONYMS/GLOSSARY

APPENDIX C

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configuration.

3.25 NDI support. The Government does not control the configuration of items procured from the commercial marketplace. This presents three potential risks:

- Incomplete or inadequate logistic support at the time of initial deployment
- A decision by one or more services to go it alone with ILS planning and development of service-unique logistics support
- Loss of the economies of scale that can be gained by joint ILS performance.

since the main purpose of this testing is to evaluate the hardware itself and to see if it demonstrates the required performance. During operational testing, however, the purpose of the test is to see how the system operates under actual conditions. Moreover, useful data can only be obtained if it is maintained and operated by personnel having the same skill levels and training as the personnel planned to operate and maintain the system when deployed in the field. If operational testing is staffed with FAA personnel having much more experience and skill than can be expected when deployed, the operational testing will give an unrealistically favorable evaluation, which though favorable to the system, provides misleading information resulting in invalid conclusions.

3.17 Accelerated programs. Compressed schedules increase the demand for critical assets during the time of normal asset shortages which can create unrecoverable delays.

3.18 Schedule slippage. Failure to understand how a schedule slippage in one functional element impacts the other elements and milestone events can ultimately delay the entire program.

3.19 Facilities planning. Failure to perform timely facility planning can result in substantial deployment delays.

3.20 The Deployment Plan. Failure to keep the Deployment Plan updated, complete, and coordinated with all concerned management personnel may have a negative impact on the program.

3.21 Deployment problems. Unreported and uncorrected deployment problems can seriously disrupt the process.

3.22 Post-production support. Continued support of the material system by the industrial base existing in the post-production time frame may not be economically feasible.

3.23 Accelerated acquisitions. Leadtimes for delivery of non-developmental items (NDI) can be extremely short, particularly for in-stock commercial items. This poses a substantial risk of deployment with incomplete or inadequate logistic support and attendant degraded readiness.

3.24 Configuration control of commercial items. The Government does not control the configuration of items procured from the commercial marketplace. This presents two potential risks:

- o Subsequent competitive procurement of the end item may lead to a totally different internal configuration with different support requirements.

- o There is no automatic guarantee that original commercial suppliers will continue to manufacture spares and repair parts to fit the Government's

3.12 Logistics test and evaluation. The main thrust of the formal Development Test and Evaluation (DT&E) and Operational Test and Evaluation (OT&E) programs is to evaluate system level performance. Logistics test and evaluation has an additional focus on component evaluation and on the adequacy of the ILS elements that comprise the logistic support structure. Failure by the ILS Manager to participate effectively in the initial development of the Test and evaluation Master Plan (TEMP) during the CE Phase risks the exclusion of critical logistics T&E and the omission of the ILS test funds required in the program and budget documents.

3.13 Data utilization. Collecting data without detailed planning for its use can lead to a mismatch of data collection information requirements and the failure to accomplish the intended purpose of the assessment (such as the update of supply support and manpower requirements and the identification and correction of design deficiencies).

3.14 T&E support package. Without an adequate test support package on site ready to support the scheduled test, it may be possible to start testing, but the chances are low of continuing on schedule. A support system failure could cause excessive delays, which can result in a schedule slippage and increased test cost due to on-site support personnel being unemployed or for the cost of facilities which are not being properly used.

3.15 T&E data. Without sufficient data being available from each test, and used properly for planning subsequent tests, it is not possible to evaluate the adequacy of the system to meet all of its readiness requirements. Without accurate failure rates, system and component reliability cannot determined. Without cause of failure established, Failure Modes, Effects and Criticality Analysis and Repair of Repairables Analysis cannot be accomplished. Integral to a data management system is the retrieval and reduction of data as well as the collection and storage. Essential to any test program is the ability to document and collect results so that they are readily available to both the engineer and logistician for analysis at completion of the test program. Lacking the necessary data, system design and ILS progress cannot be established, problems cannot be identified, and additional testing may be required.

3.16 Test scenarios. A subtle risk, particularly during DT&E, and one which can have lasting impact on the viability of a program, is testing to an unrealistic scenario. Realism does not necessarily mean that the stresses put on the system under test must duplicate those of actual service, since in most cases this is impractical; it does mean, however, that the test is planned to simulate the conditions as closely as possible and differences are carefully documented. Perhaps more significant in ILS testing than stresses applied, is the quality and skill level of personnel maintaining and operating equipment. It is expected, during DT&E, that highly skilled personnel will be operating and maintaining the equipment, meet the readiness objectives.

3.7 Component R&M data. Design and manufacture determine the mean life and failure rate of components when viewed in isolation. When the parent material system is engaged in its operational role, these same components should be expected to exhibit replacement rates substantially higher than their handbook value or inherent reliability alone would indicate. The consequences of improperly computed material replacement rates are invalid manpower requirements, incorrect supply support stockage lists, and invalid repair level analyses.

3.8 LSA requirements. Failure to establish a Logistics Support Analysis Plan that is specifically designed to meet the needs of the material system can result in excessive costs; the performance of unwanted analysis while failing to complete needed studies; and the development of excessive documentation while overlooking critical information needs. ILS lessons learned reports and discussions with ILS Managers have provided numerous examples of these deficiencies.

3.9 LCC impact on design and logistics. Life Cycle Cost is most effective when it is integrated into the engineering and management process that makes design and logistics engineering choices. This integration must start with program initiation. Once the ability to influence design is lost, it is very difficult and always more costly to re-establish. Most performance and schedule risks have cost impacts. Performance risks result from requirements which are very costly, or from engineering requirements beyond foreseeable technical capabilities for hardware development. The result can be increased cost from design, development, and test of a replacement item; contract termination costs; increased program buy; and increased O&S costs. Schedule changes can increase costs whether they are shortened or lengthened.

3.10 Accelerated programs. An accelerated system development program may be required to overcome a critical deficiency in an existing capability. This "streamlining" can pose the risk of delaying design maturation with frequent configuration changes occurring in late development, possibly continuing during initial production and deployment. The added time required to modify the LSAR and update ILS elements can lead to an initial period of decreased system readiness.

3.11 Contracting for support. The major risk area in ILS contracting, in terms of impact and the probability of its occurrence, is the failure to properly contract for data, materials, and services. Included are failures involving contractual promises by the Government to furnish material and services, and the imposition of unrealistic delivery schedules. Impacts may include degraded support and readiness, cost growth, and when repeatedly exposed, the loss of taxpayers' goodwill and confidence.

cause slippage and cost overruns to the planned program.

Site Survey Results - Historical or archaeological site survey findings could delay site construction and cause significant deployment problems.

Common Support Equipment - If common support equipment is not available as required to operate and maintain the system, then the planned program will suffer schedule and cost problems.

3. Supportability risk sources[1]

3.1 Logistics criteria. Delayed decisions on reliability and supportability requirements result in suboptimum support. Once the design is committed, the options become limited. Many early aircraft suffered from having design optimized for performance without comparable attention to support aspects such as maintenance accessibility and spare parts reliability. As a result, turn around times and operation and support (O&S) costs were excessive.

3.2 Engineering changes. A high number of design changes made during the development program can overwhelm Integrated Logistics Support planning and create an inability to fully reflect ILS and O&S cost considerations in engineering change decisions.

3.3 Readiness and supportability objectives. The system engineering process is a key factor in identifying and attaining realistic readiness and supportability objectives. If a well organized process is not started at the program inception and continued throughout the development phases, then the program risks are increased design, development, and O&S costs; schedule delays; and degraded readiness factors.

3.4 R&M requirements. The establishment of unrealistic R&M requirements (as part of the Pre-Program Initiation or Concept Exploration phases) can lead to increased design and development costs incurred as a result of excessive design iterations. This in turn can cause program delays and costly program support system restructuring in later phases.

3.5 Acquisition streamlining. The new initiatives on acquisition streamlining may impose restrictions on the program manager early on in the definition of requirements. Although intended to decrease cost and improve efficiency, casual application of such guidance could result in a loss of standardization, attendant cost increases, and the loss of documented lessons learned experience.

3.6 LSA during Concept Exploration. Failure to participate in the definition of system concepts can produce a system design in follow-on phases that does not meet supportability objectives and requires excessive or unattainable O&S costs, as well as manpower to

Subcontractor Control - If the prime contractor does not maintain adequate control of subcontractor quantity, schedule, and cost performance, then the planned program will not make its original goals.

Lack of Financial Strength - If one or more contractors have not been able to adequately finance program requirements, the required work will be delayed or curtailed.

Communication - Problems that could cause deviations from the planned program can result from failure of the subcontractor's and contractor's personnel to keep prime contractor and the PMO informed of problems and potential problems in a timely manner. Likewise, communication problems can occur if management fails to fully communicate direction to all involved in the program in a timely manner.

Forced Placement - If the program is saddled with second string personnel and managers, either in the PMO or at key contractors, then serious counterproductive events could occur causing program perturbations.

2.5 Other program problems risk category

2.5.1 Category definition. Risks falling within this category are generally somewhat different from program to program due to the unique nature or requirements of the product and program. This category does not include production related risks which have been placed in a separate category, but could be considered a subset of this category.

2.5.2 Specific other program problem risks:

Available Skills - The shortage of available personnel with the needed technical, management, and other skills to carry out PMO and contractor activities could create problems that affect the planned program.

Security Clearances - Any delays in obtaining required personnel security clearances and facility clearances will have a significant impact upon the basic program.

Secure Test Requirements - The testing of classified equipment can cause difficulties that are associated with testing classified equipment.

Test Safety - Problems that could cause deviations from the planned program can result from the new or unique requirements that testing be non-destructive or that it not interfere with other activities.

Weather - Usually severe weather related test program delays can process of, or resources needed, for system production.

2.3.2 Specific production problem risks:

Design Stability - The lack of design stability during the production phase can create serious problems in meeting production schedules and cost goals.

Familiarization - If contractor personnel are not familiar with, and do not have experience producing similar systems or equipment, problems in executing the planned program can occur.

Scarce Resource - Shortages of critical materials, components, or parts can delay production and ultimately increase costs.

Tolerance Levels - Closer than usual tolerance levels and difficulties in achieving these tolerance requirements are a subset of familiarization and can cause program problems.

Vendor Base - A shortage of an adequate number of qualified vendors necessary to ensure adequate price competition and a satisfactory supply quantity base can cause both schedule and cost problems.

Capacity - The lack of facilities and tools to produce at the desired rate (rate tooling) can prevent the production flow from reaching the desired level.

Excessive Lead Times - If longer than expected lead times for critical components or services are experienced, then the program will slip.

Advance Buy Authorization Limitations - Long lead time requirements can create problems if there is not sufficient advanced buy funding to meet the needs of the program.

Production Readiness - If the contractor fails to be adequately prepared for production, slippage will occur in the program.

2.4 Imperfect capability risk category

2.4.1 Category definition. Risks falling within this category are the result of people, organizations, or facilities not performing as well as desired or expected.

2.4.2 Specific imperfect capability risks:

Underbidding - If the contractor underbids or buys-in to get the contract and fails to provide the desired products and services on schedule and within budget, then the planned program will be significantly affected.

Continuing Resolution - The requirement to execute a program for a period of time with funds provided by a continuing resolution, and the resulting constraints associated with the continuing resolution, create unforeseen problems.

National Objectives and Strategies - Changes in national objectives and strategies will cause deviations to the planned program.

2.2 Non-program event or action category

2.2.1 Category definition. Risks falling within this category result from varied events, policy changes, decisions, or actions, not aimed specifically at the program, but disrupting original plans in some manner.

2.2.2 Specific non-program event or action risks:

Inflation - Significantly higher levels of inflation than originally forecast can create funding problems.

Legislation - Higher taxes, new labor laws affecting pay and benefits, social security increases, etc., can cause significant funding problems.

Environmental Impact - Natural disasters such as fires, floods, storms, earthquakes, etc., can cause major schedule delays and cost problems.

Source Selection Protests - Source selection award protests and related legal actions can delay the start of a program with resulting schedule and cost problems.

Labor Disputes - Labor difficulties such as strikes, lock outs, slowdowns, etc. will affect work on the program.

Requirement Changes - Requirement changes requiring changes in schedule and performance objectives will cause deviations in schedule and cost.

Operating Policies - Changes in operating policies impacting system or system support requirements can cause the program to vary from the original plan.

New Regulations - Added workload or time requirements brought about by new Congressional, DoT, or FAA direction or policy can create significant variances to the basic planned program.

2.3 Production problem risk category

2.3.1 Category definition. Risks falling within this category result from unanticipated problems associated with the concept.

1.21 Fault detection. Fault detection techniques may reveal a failure to obtain designed performance and require modification to the program.

2. Programmatic risk sources

2.1 Higher authority action risk category

2.1.1 Category definition. Risks falling within this category result from decisions or actions by higher levels of authority - generally by people knowing its impact on the program, but who are addressing larger issues.

2.1.2 Specific higher authority action risks:

Priority Risk - Problems that could affect the planned program resulting from changing priority assigned to the program and, thereby, timely access to testing facilities, funds, materials, etc.

Decision Delay Risks - Disruption of the planned program schedule resulting from delays in obtaining higher level approval to award contracts, proceed to the next phase, etc., can cause program problems.

Inadequate Program Manager Authority Risks - Planned program delays resulting from the program manager not being given adequate authority to manage the program, including having the authority to make timely cost, schedule, and performance trade-off decisions, can be a significant risk.

Joint Service Program Decision Risks - Problems and delays that could disrupt the planed program resulting from reduced joint service participation or other user decisions.

Service Roles and Mission Changes - Problems that will cause deviations from the planned program resulting from changing service roles and missions which significantly alter the planned use of the system.

Concurrency - Concurrent development or the preparation for production can cause deviations from the planned program. Concurrency often results in discovery of problems at a time when a cost premium must be paid to resolve problems and keep the program on or near the original schedule.

Funding Constraints - Lack of timely receipt of programmed funds as anticipated can cause deviation from the original plan.

Program Stretch Out - Direction to slip the program schedule from the original plan will cause funding problems.

1.8 Physical properties. If the dynamics, stress, thermal, or vibration physical requirements are different from originally expected, the planned program may not achieve its original goals.

1.9 Material properties. Material property requirements beyond what is usually expected could influence the planned program.

1.10 Radiation properties. Increased radiation stress resistance requirements can result in changes to the program from the original plan.

1.11 Modeling validity. Models used in developing mathematical and physical predictions can contain inaccuracies affecting the program.

1.12 Testing inconsistencies. Inconsistent field test results can cause increased technical risk and require retesting.

1.13 Test facility compatibility. Suitable test facilities may not be available during the required time frame and cause significant scheduling problems.

1.14 Extrapolation requirements. During the conduct of the program, the need for extensive extrapolation using field test results may hamper the assessment of the program under actual deployment conditions.

1.15 Integration/interface. New and unique design adaptability-compatibility, interface standard, and interoperability, etc., requirements can create situations that are not compatible with the original planned program.

1.16 Survivability. New requirements for nuclear hardening, chemical survivability, etc., may require revised planning in order to meet original or new goals.

1.17 Software design. Unique software test requirements and unsatisfactory software test results could result in the generation of variances to the basic planned program.

1.18 Software language. A new computer language or one unfamiliar to most of those responsible for planning and writing computer software could change the entire perspective of the planned program.

1.19 Reliability. Failure to properly forecast system reliability or failure to obtain predicted reliability growth could cause the program to deviate from its desired course.

1.20 Maintainability. Failure to obtain desired maintenance performance with a design that is compatible with proven maintainability procedures can require changes in the maintenance

APPENDIX A

RISK SOURCES - AN ABBREVIATED LIST

1. Technical risk sources

1.1 Major state-of-the art advances. These are problems that could cause deviations from the planned program resulting from greater than anticipated state-of-the-art advances. This includes areas such as:

- o Complexity/difficulty in meeting requirements
- o Percent proven technology
- o Experience in the field needed
- o Lack of work on similar programs
- o Special resources needed
- o Operating environment
- o Required theoretical analysis
- o Degree of difference from existing technology.

1.2 Numerous state-of-the-art advances. Deviations from the planned program could result from a greater number of areas than anticipated requiring advanced state-of-the-art techniques and development.

1.3 State-of-the-art advance progress. Slower than expected progress in advancing the state-of-the-art could affect the planned program.

1.4 Lack of supporting state-of-the-art advances. State-of-the-art advances expected from other programs may not be as expected and can have a significant affect on the present program.

1.5 Field failures of state-of-the-art advances. Field failures of state-of-the-art equipment types that were assumed to be ready for incorporation into the planned program can have a negative effect on the program.

1.6 Operating environment. The new system may be required to perform in an unusually harsh environment which would cause problems with the program.

1.7 Unique harsh requirements. Significant differences between existing design technology and that required for success of the new system can cause deviations in the plans for the new system.

APPENDIX A

RISK SOURCES - AN ABBREVIATED LIST

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In the spectrum of the risk management process, the weakest area at present is that of "quantifying expert judgement." Risk identification focuses on capturing the knowledge and judgements of experts. Risk assessment and analysis deals largely with mathematical statements and quantified results. Transitioning from English language statements of experts to the mathematical expressions required by the analytical tools is done inconsistently.

Strengthening this area will significantly improve the risk management process. Some rudimentary surveys of on-going research in the field indicates that this problem is a natural for the application of expert systems technology and is in fact being worked.

Risk handling is that portion of the process where the program manager attempts to reduce or contain the risks that have been identified, quantified, and analyzed. Risk handling is discussed in Section 4.5 and 5.14, which cover only a small amount of this document. That illustrates the disproportionate share of thought and literature that has gone to risk assessment and risk analysis at the expense of risk handling. The program manager is ultimately left with the question, "What can I do about it?" Risk management should benefit greatly from future efforts concentrated in developing and documenting new ideas in risk handling techniques.

9. THE FUTURE OF RISK MANAGEMENT

Risk is a fascinating subject. To those who try to understand, it looks a bit different each day - like a crystal reflecting light differently depending on the angle of view. Studying risk leads a person through a wide range of academic disciplines from rigid mathematical probabilities through sophisticated computer models into the behavioral sciences and on to the psychology of risk takers and risk avoiders.

There are many students and practitioners who are convinced they have the single right answer to the understanding and management of risk. Many confuse the tool with the result. Academicians want to quantify and analyze. Bureaucrats seek more information, avoid commitment, and criticize. Program managers live with risk. They "own" the problem.

Risk management, in the context of interest here, is being practiced in the FAA. Not as much as it should be, but more than the critics would allow. Program managers deal with risk daily. Frequently, they think of it as management without suspecting it is risk management. To that extent, the criticism is unjustified. On the other hand, many managers do not seek to identify and resolve risks early, but rather deal only with those risks that appear today. Finally, there are those who attempt to obscure risk in practice of "not on my watch" program management. To that extent the criticism is very justified.

Risk management can be practiced better than it is. Tools are available. They may not be perfect, but they can be improved. We are not living up to the existing capacity. The body of knowledge, available tools, and the computer power is available to make a major step forward in risk management.

If risk is to be properly managed, it must be recognized, acknowledged, and accepted. It must be taken out of the closet. A fundamental culture change is necessary with regard to risk.

- Program Managers must be penalized for not communicating risk rather than doing so.
- FAA "corporate management" must insist on seeing and hearing about risk and then have the courage to support the risk takers.

Risk management currently suffers from a limited vocabulary and a lack of standard definitions. Communication on the subject would be aided immensely by treatment of the vocabulary and definitions problem.

Risk management currently lacks standardized procedures and techniques. At this stage of development, lack of standardization is **NOT** a fault. There are many very intelligent people who will devise ingenious and effective techniques if given the requirements and the freedom to be creative.

CHAPTER 9

THE FUTURE OF RISK MANAGEMENT

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(e) Shielded Enclosure: Identify whether classified processors are operated within an RF shielded enclosure."

8.1.1.11 Evaluation Summary

"The overall evaluation of each proposal may include on-site inspections and results of pre-award surveys to provide information to the Source Selection Authority regarding offerors current and future capability to perform all aspects of this program. Risk assessment associated with the major areas of the program will be accomplished. In assessing risk, an independent judgement of the probability of success, the impact of failure, and the alternatives available to meet the requirements will be considered."

8.2 CONTRACTOR RESPONSIBILITY

The contractors' risk management approach should be consistent with the FAA risk management philosophy. The risk management process includes planning, identification, assessment, analysis and control. Using this process, evaluated potential risk facets such as technical, programmatic, support, cost and schedule should be assessed separately and then their interrelationships. The risk manager should coordinate and perform a risk assessment, both qualitative and quantitative, based on the probability of occurrence and severity of impact. The overall risk level derived should be described simply and easy to understand.

The contractor should be made aware through written language in the contract that information contained in the DIDs will be used for risk analysis. It should be the contractors' responsibility to make a thorough assessment of risks in proposing the contractual effort. Sufficient information should be included in the proposal to convince the governments that the contractor has recognized and quantified the risk inherent in the program. The proposal should identify areas where acquisitions by the government can aid in risk reduction. These can include items such as long lead funding and the necessity for approval of priority status materials.

In proposing a risk management system, the contractor should highlight how he can use existing internal systems (e.g., his cost and schedule control system) to provide information on risk. The contractor should also concentrate on how he can include risk considerations in formal management practices and in the various items of data provided to the Government.

identification of fallback positions, resource requirements, critical materials and processes, long lead requirements, management systems, organization and staffing, and schedule."

8.1.1.9 Quality Assurance

"Describe any QA risks you foresee for this program and actions planned to reduce the risks."

8.1.1.10 Security

"Operational Risks

(a) Level/Amount of Classified: Identify the levels of classification which will be processed as well as the estimated hours per month and percent of total material processed for each category.

(b) Sensitivity/Perishability: Identify any significant factors concerning the sensitivity and/or perishability of the classified data.

(c) Frequency of Processing: Identify the classified processing schedule which will be used; e,.g., scheduled, irregular, sporadic, random. Assess the probability of the exact hours of classified use being pinpointed by unauthorized personnel. Describe any facts of circumstances that would make such determinations difficult."

"Technical Risks

(a) Physical Control Space (PCS): Identify the radius in meters of the physical control space available around the systems/equipment/facility. Describe the barriers, doors, fences, walls, etc., that define the PCS. Describe the control exercised over the PCS during duty and non-duty hours. Describe other factors which contribute to control, such as visitor procedures, escort requirements, searches of personnel and/or vehicles, etc. (PCS is the area within which only personnel with Government security clearances are allowed unescorted access.)

(b) PCS Breaches: Identify the type and location relative to the system of any unfiltered telephone or communications lines, ungrounded or unfiltered power lines, conduits, heating and air conditioning ducts, water pipes, etc., that transgress the established PCS.

(c) Building Construction: Describe the building in which the system is housed, e.g., concrete block walls, aluminum doors, no windows.

(d) RED/BLACK Installation: Identify whether classified processors were installed in accordance with RED/BLACK criteria (i.e., installed in accordance with NACSIM 5203).

points and information requirements, and the process to be used to develop, evaluate, and implement fallback positions as required."

8.1.1.3 Reliability and Maintainability (R & M)

"Describe your approach to determining the technical risk involved in your R & M program and your approach to reducing such risks to acceptable lev ls. This discussion shall present the criteria you plan to use in determining the criticality of technologies, the techniques used to evaluate critical decision points and information requirements, and the process used to develop, evaluate, and implement fallback positions as required."

8.1.1.4 Producibility

"Describe the approach to determining the technical risk involved with the design producibility engineering program and the approach to reducing such risks to acceptable levels. This discussion shall present the criteria you plan to use in determining the criticality of technologies, the techniques used to evaluate critical decision points and information requirements, and the process used to develop, evaluate, and implement fallback positions as required."

8.1.1.5 Quality in Design

"Identify quality in design risks and factor these risks into design trade studies."

8.1.1.6 Manufacturing Research/Technology

"Provide an assessment of the likelihood that the system design concept can be produced using existing manufacturing technology while simultaneously meeting quality, rate, and cost requirements. Include in your analysis and evaluation of the producibility of the design concept: requirements for critical process capabilities and special tooling development, tests and demonstrations required for new materials, alternate design approaches, anticipated manufacturing risk, potential cost and schedule impacts, and industrial base and surge capabilities (where appropriate)."

8.1.1.7 Project Control System

"The offeror shall describe the approach system and methodology for risk management. This discussion will include how information from functional areas shall be integrated into the risk management process."

8.1.1.8 Manufacturing Planning

"Describe the initial manufacturing planning accomplishment in the following areas: production risk, risk resolution, and

8. CONTRACTOR RISK MANAGEMENT

8.1 GOVERNMENT RESPONSIBILITIES

In preparing a Request for Proposal (RFP) it is essential that the procuring agency squarely face the fact that risk management is part of the acquisition strategy. A formal plan of risk evaluation and reduction should be established by the government very early in each acquisition program. This plan should be tailored to consider the contractor and government risks. The assessment and analysis of each significant element of program risk should be continued throughout the acquisition cycle. The acquisition strategy should lower the risks to reasonably acceptable levels. The Procuring agency should include in the RFP requirements for the offerors to describe their approach to identifying and managing the risk inherent in the program. These would most probably include areas such as reliability, maintainability, producibility, quality, design, manufacturing, technology, and research along with many others too numerous to mention. In addition, the RFP should include data items such as a Risk Management Plan and a Risk Assessment Report in order to insure that the contractor will seriously plan for risk management and is continuously assessing risk.

8.1.1 Sample RFP statements

Some sample statements, that when tailored appropriately, could be used in an RFP include the following:

8.1.1.1 Executive Summary

"The executive summary shall include a proposal overview which will address expected performance and any other salient proposal characteristics, and briefly summarize them. As a minimum, risk issues of reliability, maintainability, producibility, design, supportability, work to be accomplished, trade-offs, cost, schedules, and other special considerations will be addressed."

8.1.1.2 Engineering/Design

"The offeror shall describe the engineering/technical tasks to be accomplished during the D/V program which contribute to risk reduction and definition of the substantiated system/subsystem concept. The discussion shall contain the following item:

A discussion of major technical risk items associated with the offeror's proposed system concept, including payoffs which will potentially result from the proposed approach, as well as problem areas. The approach to determining the technical risks involved in your program and your approach to reducing such risks to acceptable levels shall be identified. The discussion shall present the criteria to be used to evaluate critical decision

CHAPTER 8

CONTRACTOR RISK MANAGEMENT

ENDNOTES / REFERENCES

1. "Preference for Nondevelopmental Items" provision of the FY 1987 Defense Authorization Act.

2. Adams, C., Hevey, B., and Shaw, R., "NDI ACQUISITION, An Alternative to Business as Usual," Report of the DSMC, 1991-92, Military Research Fellows, DSMC, October 1992.

7. RISK MANAGEMENT IN THE NONDEVELOPMENTAL ITEM (NDI) AND COMMERCIAL OFF-THE-SHELF (COTS) ARENAS

Because of national and international events, that have occurred over the last ten years, Government has decreased in size and acquisition budgets are decreasing by the day. With limited funding available, and forecasts of even smaller funding levels, it has become critical that acquisition officials get the most for the taxpayer for every dollar we spend. Congress is demanding that the Department of Transportation and the Federal Aviation Administration change the way it conducts business and acquires products.

Over the years the definition of NDI has varied within Congress and the DOT. The generic and broad definition covers material available from a variety of sources with little or no development effort required by the government. The Congress identifies an NDI as: (1) any item available in the commercial marketplace; (2) any previously developed item in use by the U.S. Government or cooperating foreign governments; or (3) any item of supply needing only minor modifications to meet DOD requirements.[1] Adams, Hevey and Shaw point out that, "NDI acquisitions provide major benefits as well as challenges to the systems acquisition process and the user. Benefits include: quick response to operational needs; elimination or reduction of research and development costs; application of state-of-the-art technology to current requirement; and reduction of technology, cost and schedule risks."[2] Challenges of course include providing logistics support, product modifications, continued product availability, conducting operational requirements trade-offs, and obtaining required user reviews and approvals. -But usually NDI acquisitions benefit the systems acquisition process in reducing risk and development costs, and providing products to the users promptly.

This chapter is under development, but could not be completed before this publication was scheduled to go to press. It will be completed before the first revision of this guide is published. It is planned that sections will be included that address concepts, feasibility investigation, selection and preparation of documents, solicitation and source selection, warranties, product assurance, requirements generation, specifications, standards, test and evaluation, integrated logistics support, and final contracting.

CHAPTER 7

RISK MANAGEMENT IN THE NONDEVELOPMENTAL ITEM (NDI) AND COMMERCIAL OFF-THE-SHELF (COTS) ARENAS

ENDNOTES / REFERENCES

(1) Program Mangers must organize for risk management

(2) Risk Management is a team function

(3) Technique selection should be based on pre-determined criteria

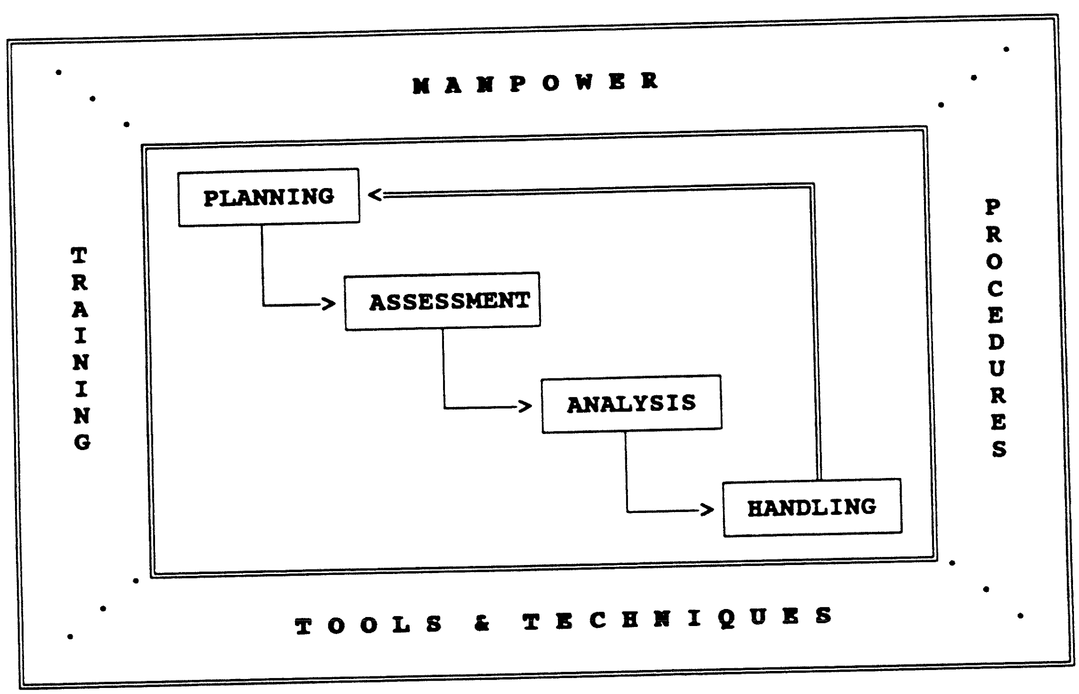
(4) Proper communication of risk information is as important as the process

(5) Program Managers should strive to develop their risk management capability.

risk management capability.

While manpower and technique selection are essential aspects of a risk management program, training and procedures are also critical for successful implementation. Risk management, as discussed earlier, is a team effort. Training in the concepts and techniques of risk management is required for full understanding and effective accomplishment of the objectives of the risk management effort. Training the PMO personnel is a necessary investment to fully reap the benefits of the risk management effort. Procedures are the documented approach to executing the risk management process. Whether contained in a formal risk management plan or not, procedures should be developed which establish direction and responsibility for the conduct of the risk management process.

Figure 6.6-1 Risk Management System



6.7 CHAPTER 6 KEY POINTS

appropriate and necessary, however, to make use of all available sources of expertise in the conduct of a comprehensive risk management effort.

6.5 COMMUNICATING RISK DATA

An important aspect of risk management implementation (which if ignored, can make the best risk assessment and analysis ineffective and incomplete) is the proper communication of risk data to decision-makers. The clear definition of the terminology employed in discussing risk, the presentation of information in a clear and consistent format within a program, and the thorough documentation of the risk data are the basics for successfully communicating information about risk.

No standards exist for the clear definition of terms for risk. While this handbook has presented a basic framework for discussing risk, an argument can be made that no universal standard can be employed to compare risk across programs. Given these circumstances, the clear, unambiguous definition of the terminology used to present risk related data must be accomplished for common understanding among program participants and higher command levels.

Beyond terminology, for a full understanding of the risk information, the process and the content of the conduct of the risk management effort must also be captured and communicated. The sources of data, the assumptions made about the program, the methodologies of assessment, analysis, and handling techniques used, and the sensitivity to the risk data of changes in the assumptions, must all be consistently documented and communicated to effectively implement risk management.

Last, though the subject of risk is complex, the presentation of findings and risk data should be straightforward and in a usable format. The depiction of a cumulative probability distribution function from a Monte Carlo network analysis may be informative to an analyst, but meaningless to the decision-maker reaching for a solution to the problem. Risk data must be presented in a usable format that communicates the essential elements of the risk management effort.

6.6 DEVELOPING A RISK MANAGEMENT CAPABILITY

To successfully implement the risk management process, the program manager must also address the capabilities of the PMO to execute that process. The discussion of risk management implementation typically centers around the evaluation and selection of the tools and techniques to be used and the source of manpower to use them. Much of this chapter has focused on these two topics. Figure 6.6-1 illustrated that there are basically four elements of a risk management program which support the execution of the risk management process. Each of these elements should be considered when developing an organic contractor may be more objective, but is controlled to a degree by the PMO. The weakest source in objectivity is the prime contractor for obvious reasons, and generally the strongest source comes from the independence of the functional support office. The PMO and the prime contractor are rated as being familiar with a program and responsive to it. The support contractor is rated as moderate due to the learning that must be accomplished to conduct an assessment and analysis. Keeping the support contractor at a certain level of involvement to improve responsiveness and familiarity is a direct cost to the program. The responsiveness and familiarity of the functional support offices varies. They typically suffer to a lesser degree from the need to learn the program in order to accomplish their risk management task.

Table 6.4-1 Resource Selection Criteria

	PROGRAM OFFICE	FUNCTIONAL SUPPORT OFFICE	PRIME CONTRACTOR	SUPPORT CONTRACTOR
CAPABILITY	TECHNIQUE AND ORGANIZATION DEPENDENT	TECHNIQUE AND ORGANIZATION DEPENDENT	TECHNIQUE AND ORGANIZATION DEPENDENT	VARIES
AVAILABILITY	VARIES	VARIES	GENERALLY AVAILABLE/DIRECT COST	AVAILABLE/DIRECT COST
OBJECTIVITY	PROGRAM ADVOCATE	STRONGEST	WEAKEST	CONTROLLED BY PROGRAM ADVOCATE
RESPONSIVENESS FAMILIARITY	STRONG	VARIES	STRONG	MODERATE/DIRECT COST

In the final assessment, for the selection of a source to accomplish a major part of a program's risk management effort, the program manager should first look to the PMO itself. The benefits in program definition and understanding in conducting the risk management effort, in addition to the information derived for decision-making for the handling of risk, merit the rigorous attempt to accomplish the effort in-house. It is the job. The program manager has basically four sources to task in conducting a risk management program.

(1) Program office

(2) Functional support office

(3) Prime contractors

(4) Support contractors

Each source has been used successfully by different programs though most respondents to the DSMC Risk Management survey attempted to accomplish the majority of their efforts within their own PMO.

Each source has its strengths and weaknesses to consider and certain criteria should be used when selecting a source. The first criteria is simply the *capability* of the source to accomplish the risk management task. Capability refers to the knowledge and understanding of applying the risk techniques. A second criteria is the *availability* of the resources to accomplish the risk management task. There are only a finite number of hours in a day and days in a week. Though a PMO may be highly skilled and very experienced, their time commitments may necessitate finding other sources for the conduct of certain aspects of the risk management effort. *Objectivity* is another criteria which should be considered. By definition, the PMO is an advocate of the program and as such, the results of their analysis may be viewed externally as prejudiced. Depending on the situation and ultimate use of the results, this may be an important criteria for consideration. The last factor considered is the *responsiveness and familiarity* of the source. This criteria aggregates the technical and program knowledge of the source with the ability to respond to program changes.

Table 6.4-1 captures in a matrix an evaluation of the sources against these four criteria. In terms of capability, the program office's ability generally is technique and organization dependent. Some program offices have individuals who have developed skills and are experienced in various risk techniques. Similarly, those PMOs operating in matrixed organizations who turn to functional support offices will generally find capabilities that vary by technique and organization. the DSMC Risk Management survey found an increasing awareness and capability among PMOs for the conduct of risk management efforts. Prime contractor's capabilities are also dependent on the specific technique and organization. In general, support contractors are available with the capability to accomplish risk management tasks. The availability of the source obviously varies in the government. It is generally available from the prime and support contractors, but at a direct cost. In terms of objectivity, the PMO is viewed as a program advocate and as such, may be suspect. The support funds to resolve problems caused by risk.

6.3.2.8 Selection Criteria for Performance Tracking Technique

Resource Requirements: The performance tracking technique requires a small amount of additional time above what is normally required to manage a program. Most of this time is in the initial setup of indicators to be used and tracked in monitoring program progress. The level of effort can vary based on contractor reporting requirements as set out in the contract. With this technique, involvement of the contractor is desirable in the initial setup of indicators - their level of involvement will directly affect the program office effort in getting the indicators in place. The use of a spreadsheet and PC are desirable, but not mandatory. Once the indicators are in place, minimal resources are required to maintain.

Application: This technique can be used in most of the categories of Table 6.3-1. Since the technique focuses on the monitoring of progress once an item is contracted for, there is little value in using it for the Source Selection process.

Output: The output of the technique is very good in general. If the appropriate indicators were selected, a quantified measure for each potential problem area is graphically presented. These are extremely useful for both management of the program and communication of the program status to all levels of decision-makers.

6.3.3 Technique Selection Summary

As discussed, the selection of a risk assessment and analysis technique is a function of the application, the information needed, and very importantly, the resources required versus the resources available. Much of the hesitation to implement many of these techniques comes from the concern that they are too time consuming, especially for a small PMO. The results of the DSMC survey and an understanding of the different techniques indicate otherwise. The use of Transition Templates, Risk Factor Methods, and Performance Tracking techniques all can be tailored to provide valuable information without considerable expenditures of resources. Even the network analysis technique can be used selectively with positive results with less than a major team effort. The key to technique selection and successful risk management implementation is the clear communication of the objectives, and the integration of risk management concepts and activities into the normal course of managing the program.

6.4 <u>RISK MANAGEMENT RESOURCE SOURCES</u>

In implementing a risk management effort, the program manager must acquire and allocate the proper resources to tackle available. The analysis computations can be obtained within minutes after the required data has been obtained. Often the required cost element uncertainty data must be based on the judgment of PMO personnel. The program managers commitment is needed to assure PMO personnel provide this information in a timely manner.

Application: The PMO survey indicated use of this analysis technique for program preparation, source selection, and program status reporting.

Output: The accuracy of the output results is limited by the subjective nature of most of the input data used to carry out this type of analysis. The analysis does nothing to increase visibility at a lower level of detail. It does the computation by aggregating detailed information into overall program cost risk information. The overall usefulness of this type of analysis for actually detecting risk, controlling risk, or reducing the impact of risk is limited. However, it can be used to display cost risks known to exist at the cost element level in an aggregate manner the way some management officials wish to see it.

6.3.2.7 Selection Criteria for Risk Factor Technique

General: This analysis method has been widely used to develop an estimate of the funds required to cover added costs resulting from various risks felt to be associated with each of the various WBS elements associated with the program.

Resource Requirements: A cost estimate broken out by WBS element is a prerequisite for this technique. Obtaining WBS element risk factors from adequately qualified experts is the bulk of the effort. The required computations are usually so easy that they have been carried out quickly with only a hand-held calculator. However, if a simple program is not already available to carry out the required computations, it would be best to quickly set up the computations on an electronic spreadsheet.

Application: This analysis method can only be used when a cost estimate broken out by WBS element is already available. It can quickly provide a systematically derived estimate of required funds to cover the costs resulting from risky aspects of the program. It is applicable to any type of product or size of program. It is probably more applicable to smaller programs where the resources and time required to apply more sophisticated techniques cannot be justified. The method can best be applied when PMO personnel with experience on several other programs are available to provide judgments of the level of risk involved with each of the WBS elements.

Output: The output of this analysis method is an estimate of the total funds required to complete the program, including costs can be an important design consideration. There are both PMO unique and general purpose life cycle cost models widely used. The availability of the electronic spreadsheet has greatly facilitated the development and use of life cycle cost models by PMO personnel.

Resource Requirements: Performing a life cycle cost analysis, even one involving many estimates for different scenarios or sets of assumptions can be done relatively easily and quickly, if the model is already available. For large and complex programs, the input data collection process may involve many sources. Even the most complex life cycle cost models can be run on computers of the size available to most PMOs. If a PMO unique model is not available and must be developed, the resource requirements to do this can be greatly reduced if a demonstrated model for a similar system can be tailored to the PMOs needs.

Application: Since cost is an important management consideration, the results of life cycle cost analysis are applicable to many PMO decisions and activity areas. Once a PMO computerized life cycle cost analysis capability has been developed, it is of significant value whenever a quick assessment is needed of the cost implications of design, production rate, or other program changes.

Output: The overall accuracy of life cycle cost analysis is medium. Usually such estimates can be improved if significant additional time is taken to have the prime contractor take a more detailed look at how changes would impact a program. Life cycle cost analysis is better for analyzing the differences among alternatives than accurately predicting future costs. Depending on the specific life cycle cost model, the analysis output can provide considerable detail as to where cost might change as the result of program changes. The overall usefulness of life cycle cost analysis is high due to the timely insight it provides relative to a wide range of management decisions.

6.3.2.6 Selection Criteria for Cost Risk/WBS Simulation Model

General: This type of analysis model aggregates the cost uncertainty due to risk for any number of cost elements into a distribution of the cost uncertainty for the entire project. Both Government and commercial software programs are available to carry out this type of analysis.

Resource Requirements: This analysis method is easy to use after a few hours of hands-on experience. Available programs come with instructions; however, obtaining and substantiating sound values for all the cost element uncertainty information needed to use the method may be difficult. Ideally, the best source of such information would be past experience on similar programs, however, adequate information of this type is seldom of risk or the basic program cost estimate changes.

Output: The estimating relationship method output is generally a percent value. This value multiplied by the basic program cost estimate provides an estimate of the management reserve or risk funds that must be added to the basic cost estimate to assure the budget includes adequate funds to cover the added costs that will be incurred because of the risks associated with the program. The accuracy of this method is considered low primarily because the historical data bases upon which such models are based are small, and it is often hard to accurately define what funds were spent to address risk on past programs. This method provides little or no detail with respect to which parts of the program are more risky, and therefore, more likely to require additional funding. Since there are so few models of this type available, and even their use are subject to question, the overall utility of this method must be considered low.

6.3.2.4 Selection Criteria For Transition Templates Technique

Resource Requirements: This technique requires little additional resources above what is normally necessary to properly manage a program. There are no special hardware/software requirements and the technique is easy to use. It does require discipline on the part of the program management office to regularly review and compare progress against each of the template areas.

Application: The Transition Templates can be used in most of the application categories in Table 6.3-1. The technique is only indirectly useful in the CIP/Budget category because it deals with preventive technical aspects rather than cost issues. It can, however, provide insight into the driving forces behind cost and a contractor's methodology for managing a program in a source selection situation.

Output: If the user properly documents the results of his analysis, the output will provide a traceable management checklist that can be used to make sound decisions on technical issues. Again, discipline is a key issue in determining the usefulness of the output. If each of the templates is examined in detail, the user will have a firm understanding of the technical risks faced in the program. Skipping templates because there is no "apparent" risk may save time, but may also miss key problem areas.

6.3.2.5 Selection Criteria for Life cycle Cost Analysis Technique

General: Life cycle cost analysis has been used widely in recent years as a result of growing concern about rapidly increasing operating and support costs. Since economic considerations are an integral part of engineering, life cycle reason than it forces managers to detail plan before the execution of a program.

6.3.2.2 Selection Criteria for Decision Analysis Technique

Resource Requirement: The decision analysis method is a much simpler technique than network analysis. Because of this, the resources required are significantly less. PM commitment, while required, does not need to be as high as with network analysis.

Application: As with network analysis, decision analysis lends itself well to all of the potential applications listed.

Output: If the program can be accurately modeled, the output will be accurate. The level of detail is specified by the program manager predicated on what he deems necessary. The utility of decision analysis is not as high as network analysis because it does not provide the same diversity of output or address the myriad of questions that network analysis does.

6.3.2.3 Selection Criteria for Estimating Relationships Technique

General: The estimating relationship method is not well understood by many. Many PMO survey responses indicated they had used the technique when they had really used parametric cost estimating methods for some or all of the program cost estimates. Such analysis is more accurately described as all or part of a life cycle cost analysis. The estimating relationship method is defined by the use of parametric estimating methods to estimate risk or management reserve fund requirements. There are currently very few parametric cost models available with which to do this.

Resource Requirements: The primary requirement is the availability of a parametric cost model specifically designed to estimate management reserve or risk funds as a function of one or more program parameters. If such a model is not available, one to three months may be required to develop one. If the required historical data is not available, it may be impossible to develop the required cost model. If a satisfactory model is available, if generally takes only a few days to use it. However, the program manager must support its use so key program personnel will provide the cost analyst with timely judgments or information needed to input the model. The model equations are usually so simple that a handheld calculator can be used to compute required management reserve fund requirements.

Application: The primary use of this method is to compute the management reserve or risk funds to be included in CIP and BES funding requirements. It has little or no use for other applications. This is a very easy technique to recompute and update as the program progresses over time and either the level

It is more important to note that some techniques have more applicability to specific program phases. Likewise, each technique yields different information than others. Table 6.3-2 summarizes the technique applicability for each program phase and addresses the type of information likely to be received. This table shows "general" guidelines. There have been, and will continue to be, specific applications that are/will be exceptions to the guidance represented in this table. Technique selection should not be based solely on program phase. The type of information desired as a result of the execution of a particular technique must also be considered. For example, while networks are not the optimum risk analysis tool in production, they may be desirable because of their value in planning and control while transitioning from development to production. Similarly, networks may serve a somewhat different purpose in the different phases.

A more thorough discussion of each technique was presented in Chapter 5. This evaluation will summarize the key characteristics to be considered in making the proper selection of a technique.

6.3.2.1 Selection Criteria for Network Analysis Technique

Resource Requirement: The resources required to apply the network analysis technique is dependent on a few factors. One of which is whether or not the networks already exist for the program. If so, they can be utilized for the risk models and much labor can be saved. The scope of the program and the level of detail being modeled also impact the resource requirements (with the larger scope and greater detail requiring significantly more resources). When doing network risk analysis, special software is required. Also, if plots of the networks are desired, plotting equipment will be needed. Since the process of building the networks, capturing expert judgment and understanding the software are not simple tasks, ease of use would be rated as low. PM backing is mandatory for successful network analysis because of the resources required, and the degree of difficulty associated with the process. Although the PM's personal involvement is slight to moderate, the members of the program team must be convinced of the manager's commitment to the task.

Application: Networks have a high degree of utility as discussed in Section 5.8, therefore all of the applications listed are relevant.

Output: With respect to output, the accuracy of the analysis is a function of the validity of the network itself and the PDFs constructed for each activity. The level of detail is determined by management so it can be low, medium, or high. The utility of the networks is generally high, if for no other

Table N-1 Requirements Risk Evaluation Criteria
Entry to Production Phase

NOTE THAT UNDER CURRENT FAA ACQUISITION PROCESSES
THIS APPENDIX IS NOT NORMALLY APPLICABLE.

USE
DEMONSTRATION/VALIDATION
AND
ENGINEERING AND MANUFACTURING DEVELOPMENT GUIDELISTS
FOR PLANNED MODS AND UPGRADES

This appendix will be re-evaluated and readdressed before release of the first revision of this guide.

Table N-2 Cost/Schedule/Management Risk Evaluation Criteria - Entry to Production Phase

AREA	LOW	MODERATE	HIGH
1. Resource Estimating Tools	Available; used by experienced people.	Available, but limited experience on use.	Not available; not used.
2. Basis for Cost/Schedule Estimating	Extensive database of comparable systems.	Calibrated production or limited database.	New system type or technology; no available data.
3. Program Schedule	Sufficient to allow retest/redesign of a reasonable number of problems.	Minimal reserve for retest/redesign.	Based on "all successes" in design validation and testing.
4. Funding Availability	Satisfies all planned program activities.	Limits one critical program activity.	Does not allow risk reduction activities.
5. Integration Responsibilities	Defined and funded; controls in place and effective.	Defined, but not fully funded; controls still TBD.	Not defined or no funding for integration.
6. Quality Assurance	Planned and implemented.	Planned only.	Not planned.
7. Government-Furnished Information (GFI)	Available to PMO and adequate.	Probably adequate, but must be developed.	Not adequate; must be developed.
8. GFE/GFP (Production)	Available from stock; no transportation difficulties.	Must be ordered and manufactured, but lead time 80% or less than time to first need.	Not available or lead time longer than first need date.
9. GFE/GFP (Development)	Available from stock; ready for use in development.	Not readily available, but simulator/work-around available.	Not available; no simulator or work-around available.
10. Key Metrics	Developed and used.	Developed; process not fully in place.	Not developed.
11. Program Office Staffing	Fully manned; sufficient experience in house.	Manned in all key areas; some training needed.	One or more key areas not manned or by inexperienced personnel.
12. Concurrency - Use Of	All system development completed before production started.	Long lead items ordered before their qualification completed.	Major production initiated before testing completed (on those items).
13. Field Support - Deployment Site	On-site team planned, including engineering.	On-site team; phone in engineering support.	No on-site team or no engineering support planned.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

Table N-3 Engineering (Hardware/Software) Evaluation Criteria - Entry to Production Phase

Sheet 1 of 2

AREA	LOW	MODERATE	HIGH
1. Design Maturity	Little or no change expected to baseline.	Some change in baseline expected.	Rapidity changing requirement; no baseline.
2. Critical Performance	Meets or exceeds requirements.	Performance marginal.	Inadequate performance.
3. Design Growth Capacity	Margins equal or exceed historical requirements.	Some capacity, but less than historical requirements.	No growth capacity in one or more key areas.
4. Computational Reserves (memory, timing, IO, etc.)	Requirements less than 50% of capacity.	Requirements between 50-70% of capacity.	Requirements greater than 70% of capacity.
5. Functional Configuration Audit/Physical Configuration Audit (FCA/PCA)	Both completed.	FCA completed; PCA to be done.	FCA and PCA not completed.
6. Qualification Testing	All passed.	80% complete or problems in one area (solution available).	Less than 80% complete or major problem in one or more areas.
7. Qualification Testing	Performed at worst case limits derived from environmental profiles.	Performed at worst case limits specified in MIL-STDs/MIL-SPECs.	Performed at nominal environmental limits.
8. Qualification Test Units	Qualification units fully production representative.	Units mostly production representative.	Units not production representative.
9. Subsystem Test Limits	Established by measuring environment seen by each LRU/subsystem.	Established by analysis of environment.	Established by using system environment.

RISK INCREASING FACTORS	RISK REDUCING FACTORS:

Table N-3 Engineering (Hardware/Software) Evaluation Criteria Entry to Production Phase

Sheet 2 of 2

AREA	LOW	MODERATE	HIGH
10. Test Environment Acceleration	Factors used have solid proven basis.	Factors have limited basis.	Factors based only on theoretical considerations.
11. Operational Environment	Limitations studied/tested; user can tolerate system effects.	Limitations considered, but no formal analysis of effects.	Limitations not addressed.
12. Hazardous Materials	None required.	Some use; adequate controls in place.	Major use required or inadequate controls.
13. Safety	No major or critical hazards exist.	One or more major hazards exist.	One or more critical hazards exist.
14. Security	Vulnerabilities eliminated or at acceptable levels.	Vulnerabilities exist; acceptable work-around available.	Vulnerabilities exist; no acceptable work-around available.
15. Test Parameters - Funnel Concept	Test margins increase from component to system level.	Test margins same from component to system level.	Test margins inconsistent from component to system level.
16. Use of Standard Parts/Program Parts List	In place and widely used.	In place; used occasionally.	Not in place.
17. Factory Testing/Design Life	Consumes less than 10% of system life.	Consumes less than 20%.	Consumes more than 20%.
18. Configuration Management	Formal process in place; no deficiencies.	Process in place; minor deficiencies.	No process or major deficiencies.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

Table N-4 Acquisition Logistics Risk Evaluation Criteria - Entry to Production Phase

Sheet 1 of 2

AREA	LOW	MODERATE	HIGH
1. Design	Stable design.	Minor changes needed.	Major changes needed.
2. Supportability Parameters (test results, including R&M)	Meets all.	Within 10% of all.	Deviates more than 10% from one or more parameters.
3. System Diagnostic Requirements	All aspects (BIT, ATE, manual) meet requirements.	One or more elements deficient; acceptable alternative exists.	One or more elements significantly deficient; no acceptable alternative.
4. Maintenance Planning	Use and timing of ICS/CLS/organic settled; funding sufficient.	Minor decisions needed or small funding shortfall.	Major decisions needed or major funding shortfall.
5. Level of Repair (LOR) Decisions	All completed.	95% completed; only minor remain.	Less than 95% completed.
6. Depot Assignments	All completed.	95% completed; only minor remain.	Less than 95% completed.
7. Support Funding (at start of production)	100%.	90%.	Less than 90%.
8. Facilities Planning/Execution	Meets deployment needs.	Does not meet all needs; work-arounds available.	Does not meet all needs; work-arounds not available.
9. BIT/ATE Vertical Compatibility	Compatibility between maintenance levels incorporated.	Partially considered.	Not considered.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

Table N-4 Acquisition Logistics Risk Evaluation Criteria - Entry to Production Phase

Sheet 2 of 2

AREA	LOW	MODERATE	HIGH
10. Training Equipment Design	Concurrent with system, but not completed until system design release.	Completed concurrent with system design.	Initiated after system design has been completed.
11. Technical Orders - Present Status	Validated; verified.	Validated; not verified.	Not validated.
12. Technical Orders - Planning	Verified prior to first delivery.	Verified prior to Required Assets Availability (RAA) date.	Verified after RAA.
13. Software Tools	Documented; validated; in place and being used.	Available; validated; some development required.	Not available, no priority; major development required.
14. Support Equipment - Test Results	Operationally acceptable.	Minor operational deficiencies.	Major operational deficiencies.
15. Support Equipment - Availability	Sufficient numbers; deliveries meet user needs.	Marginal availability or delivery schedule slightly behind need.	Not available in quantity or at dates needed.
16. Spares Planning - Rates/ Factors	Based on validated test and operational usage data.	Based on limited test data or operational usage.	Based solely on design analysis and operational estimates.
17. Spares - Availability	Sufficient numbers; deliveries meet user needs.	Marginal availability or delivery schedule slightly behind need.	Not available in quantity or at dates needed.
18. Maintenance Transition Planning	Organic capability ready prior to end of contractor support.	Organic capability ready at end of contractor support.	Organic capability not fully ready at end of contractor support.
RISK INCREASING FACTORS:		**RISK REDUCING FACTORS:**	

Table N-5 Manufacturing Risk Evaluation Criteria - Entry to Production Phase

AREA	LOW	MODERATE	HIGH
1. Industrial Base	Meets all needs (Government/commercial).	Meets Government needs only.	Cannot meet Government needs.
2. Design Producibility	Optimized.	Addressed in design; minimum needs met.	Redesign required to meet minimum production needs.
3. Technical Data Package	Completed; verified by independent examination.	Drafted; minor corrections needed.	Major effort to complete still needed.
4. Design Stability (ECP rate)	Design stable; no changes to production methods/tools.	Approaching stability; small changes to production methods/tools.	Not stable; major changes to production methods/tools.
5. Surge/Mobilization Capacity	Able to meet defined surge requirements.	Can increase capacity within required lead times.	Cannot increase capacity within required lead times.
6. Manufacturing Technologies	Exist and demonstrated in production setting.	Exist, but must be improved prior to use.	Need development; work not started.
7. Work Instructions	Completed; proofed using production workers/processes in a representative environment.	Developed for key areas; critical process demonstrated in a representative environment.	Not developed or need to be proofed in a representative environment.
8. Technologies/Material/Manpower	Available on open market; 2 or more stable sources.	Known source limitations/ instability.	Not available in required amounts.
9. Tooling Development	Concurrent with system design.		After system designed.
10. Special Tooling/Test Equipment	Exists and used on similar products.	Requires some new or modified equipment.	Not currently available or design proofed.
11. Critical Equipment	Not single point failure.	Single point failure; work-around exists.	Single point failure; no work-around.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

Table N-5 Manufacturing Risk Evaluation Criteria - Entry to Production Phase

Sheet 2 of 3

AREA	LOW	MODERATE	HIGH
12. Process/Tooling Proofing	Completed successfully.	90% completed.	Less than 90% completed.
13. Production Equipment Quantity	Based on formal analysis.		No formal analysis.
14. Production Equipment Availability	In place.	On order; delivery before need date.	Not on order or delivery after need date.
15. IMIP/MANTECH	Approved and implemented.	Identified and approved; program dependent upon project success.	Not detailed or approved; program needs project success.
16. Environmental Compliance*.	In total compliance.	Some minor corrective action needed.	Major compliance issues; large costs to comply.
17. Parts/Assemblies Availability	Commodity item available from multiple sources.	Two sources available.	Single source only.
18. Parts/Assemblies Order Lead-times	Well within required times.	Expected lead-times equal required times.	Greater than required times.
19. Parts/Assemblies Capacities	Available capacity exceeds demand.	Capacity equals demand.	Capacity less than demand.
20. Long Lead Availability	Ordered/delivery within lead-time.	Partially ordered or delivery longer than lead time.	Not ordered.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

*(Public/EPA and local laws concerning hazardous requirements, wastes, emissions, processes and materials from factory operations.)

Table N-5 Manufacturing Risk Evaluation Criteria - Entry to Production Phase

Sheet 3 of 3

AREA	LOW	MODERATE	HIGH
21. In-coming Material Quality Process	Vendors have demonstrated process controls (e.g., less than 100 defects per million).	Rescreening process (100% or sampling) used.	No process in place.
22. Contingency Planning (critical areas)	Adequately developed.	Partially developed.	Not adequately developed.
23. Yield Rate Planning	Ramp-up planning includes yield ramp-up.		Ramp-up planning based on mature process yields.
24. Manufacturing Screening	In place and environments validated in EMD.	In place; environments not validated.	Not in place.
25. Software for Special Test Equipment	Adequately debugged and verified.	Marginally debugged; needs added verification.	Not debugged or verified.
26. Process Characterization Results	Capabilities/limits well defined and meet program goals.	Moderately defined or minor impact on program.	Poorly defined or major program impact.
27. Process Variability	Measured in production environment and meets program goals.	Measured in test environment or minor program impact.	Not measured.
28. CM - Manufacturing Process	Formal process in place; no deficiencies.	Process in place; minor deficiencies.	No process or major deficiencies.
29. Built-In Test and Production Testing	Requirements worked together; BIT includes production test capabilities.		Requirements worked separately; BIT does not include production test capabilities.
RISK INCREASING FACTORS:		RISK REDUCING FACTORS:	

APPENDIX O

CONTRACTOR CAPABILITY/RISK EVALUATION CRITERIA

APPENDIX O

CONTRACTOR CAPABILITY/RISK EVALUATION CRITERIA

The following guidelist provides a basic set of questions regarding a potential contractor's capabilities. The program office is responsible for tailoring or augmenting this list as needed for it's specific circumstances. The guidelist can also be used to evaluate in-house Government capabilities.

Table O-1 Contractor Capability/Risk Evaluation Guidelist

	CRITERIA			
CAPABILITY	EXCEEDS	MEETS	MARGINAL	POTENTIAL PROBLEM AREA
CONTRACTOR EXPERIENCE				
1. Does the contractor have experience in using the various technologies and software tools/languages proposed for the system?	Used previously; multiple times.	Used previously; one time.	Used elements; not in toto.	No previous application.
2. How long has the contractor's development organization been together (e.g., how long has the unit that will do the work been established)?	Over 3 years.	1 to 3 years.	Less than 1 year.	New organization.
CONTRACTOR PERSONNEL				
3. What is the experience of the key senior personnel (senior program management, lead technical staff, including manufacturing and logistics) in developing a system using the proposed technology and complexity (including integration issues)?	Developed this type of system before; multiple times.	Developed this type of system before; once.	Developed less complex variation of this type before.	Have not developed any variation of this type of system before.
4. If the program requires personnel requiring critical skills (e.g., Ada programmers, designers for new technologies, software support, etc.), what percentage can be obtained from internal resources?	100% available.	90% available.	50% available.	25% available.
5. Are the personnel (all types) needed to do the job available from within the company, or will they have to be hired externally.	100% available.	90% available.	50% available.	25% available.

Table O-1 Contractor Capability/Risk Evaluation Guidelist

CAPABILITY	EXCEEDS	MEETS	MARGINAL	POTENTIAL PROBLEM AREA
6. If external hiring will be required, what are the labor market conditions (within the company's normal hiring area for the skills under consideration) for the required labor skills?		Skilled personnel readily available.	Barely available	Insufficient people available -- boom market
7. Has the contractor identified, by name, the personnel who will lead each of the design teams?	Yes and each design team fully identified.	Yes.	Only team leaders for critical teams identified.	No.
8. What is the contractor's turnover rate, for both technical personnel and production workers?	Very low rate.	Low rate.	Moderate rate.	High rate.
DESIGN PROCESSES				
9. Does the contractor use formal, documented, proven design processes for hardware and software development and system integration?	Documented and proven in past usage for all design areas.	Documented and proven for key design areas only.	Documented, but not proven or critical area(s) missing.	No formal procedures developed.
10. Does the contractor have a formal, documented systems engineering process for managing the requirements analysis/allocation/design integration process (including clear process for flowing requirements to appropriate design teams/ designers)?	Yes; validated on several previous efforts.	Yes.	Yes, but has some minor deficiencies.	No.
11. Does the contractor have a requirement allocation/traceability and requirement verification process tracking system in place?		Yes; automated system	Yes; manual system	No.
12. Does the developing contractor use modern programming practices (as established for the software language used) for software development?		Routinely and fully used.	Experienced in aspects; not fully used.	No use of such practices.

Table O-1 Contractor Capability/Risk Evaluation Guidelist

CAPABILITY	EXCEEDS	MEETS	MARGINAL	POTENTIAL PROBLEM AREA
13. Does the contractor have and use design standards for both hardware and software development?	Yes; validated on previous efforts.	Yes; in process of being validated.	Yes; not validated.	No.
14. Does the contractor have a formal process in place for determining compliance with corporate design processes and standards?	Verification embedded in design tools.	Verified by periodic reviews by senior personnel and peers.	Verified by sampling checks by senior personnel.	No evidence of any process.
15. Does the contractor have a formal process/standards improvement process in place, where lessons learned from previous efforts are used to update the documented design processes and standards?	Formal process in place; continual updates of documents.	Formal process in place; regular updates of documents.	Informal process only.	No evidence of any process.
16. Does the developing contractor use an integrated design team (hardware, software, logistics, manufacturing, support, test) or concurrent engineering concepts?	Yes; using on other current efforts.	Yes; using on other current efforts.	Yes; first application.	No.
17. Is there a designated manager for each configuration item (CI) and computer software configuration item (CSCI)? Do responsibilities include manufacturing (CI only) and logistics concerns?	Yes; including full responsibility for logistics and manufacturing issues.	Yes; but limited responsibility for logistics and manufacturing issues.	Yes, but limited responsibility for logistics and manufacturing issues.	No, or no logistics or manufacturing responsibilities.
18. Is there a designated manager for each system interface? Does the manager have the authority to settle interface integration issues?		Yes.	Yes, but integration issues must be elevated to program management for resolution.	No.
19. Does the contractor have the developing engineer perform design analyses concurrent with design?	Yes; designer has tools to do as part of design.	Yes; with support from specialty group.	Done by designer after the fact.	Done after the fact by specialty group; no designer support.

Table O-1 Contractor Capability/Risk Evaluation Guidelist

CAPABILITY	EXCEEDS	MEETS	MARGINAL	POTENTIAL PROBLEM AREA
20. Does the contractor routinely perform design analyses on all program requirements, prior to testing?		All program requirements.	Major/critical only.	Per SOW only.
21. Does the contractor use a structured design review process to do in-process evaluation of the design?	Incremental internal reviews with experts from outside the developing organization.	Incremental internal review with members of the developing organization.	Comprehensive internal review prior to Government review.	Only done as formal review with Government.
22. Does the contractor have a formal process for performing trade studies, including scheduling of studies, levels of review, personnel assigned, and analytical tools available?		Yes.		No.
23. Is there a defined process for reporting to the corporate senior management (1-2 levels above the program manager) program status and problem areas requiring additional corporate resources? Do responsibilities include manufacturing (CI only) and logistics concerns?	Yes; senior management has complete visibility into program. Rapidly works resource issues.	Yes.	Periodic reporting only.	No evidence of significant senior involvement (written report only).
DESIGN TOOLS				
24. Does the contractor have the necessary types of design tools to perform an accurate, timely job?	Yes; designer has tools to do as part of design.	Complete suite for required effort.	Tools available for key tasks.	Lacking tools for key tasks.
25. Are the contractor's development tools automated or manual?	Fully automated with complete integration between tools.	Fully automated.	Key tools automated.	Manual.
26. How much experience does the contractor have with his key design tools?	Greater than 3 years.	1 to 3 years.	Less than one year.	New.

Table O-1 Contractor Capability/Risk Evaluation Guidelist

CAPABILITY	EXCEEDS	MEETS	MARGINAL	POTENTIAL PROBLEM AREA
27. Does each person have ready access to the design tools necessary to accomplish the job?	Individual workstation for each; linked to corporate resources for major analytic efforts.	Individual workstation for each; not linked.	Shared tools only; multiple copies available.	Single copy of tool; single facility used by each member.
28. Does the contractor have a formal training program in place on the use of design tools?		Formal training in dedicated training environment.	Formal on-the-job (OJT) only.	Informal OJT only.
SUBCONTRACTOR MANAGEMENT				
29. Does the subcontractor have a proven, documented subcontractor management process?	Documented process; proven in multiple use.	Documented process; proven at least once.	Documented process; not proven or minor deficiencies in past use.	No formal process or major deficiencies in past use.
30. Does the contractor have satisfactory experience with its key subcontractors?	Worked together well on multiple efforts.	Worked together on one previous job.	Some problems on previous effort(s).	Never worked together or problems on previous effort.
31. Does the contractor use past performance as a key selection factor in selecting subs?		Formal past performance effort in place and used.	Informal process only.	No evidence that past performance is a major factor.
32. Does the contractor have an established process for maintaining communications between the prime and the subs?	Collocated development teams.	At least one prime representative at each sub location.	Dedicated focal point for each subcontractor.	Shared focal point for each subcontractor.
33. If a collocated effort is not used, does the contractor provide technical support and technical monitoring for each subcontractor?		Dedicated technical personnel for each.	On-call support.	Part of regular engineering staff; added duty.
34. Do the contractor and the subcontractors use the same development tools?		Same tools used by both.	Minor differences.	Major differences.

Table O-1 Contractor Capability/Risk Evaluation Guidelist

CAPABILITY	EXCEEDS	MEETS	MARGINAL	POTENTIAL PROBLEM AREA
35. Does the contractor have a satisfactory requirements flow-down process?		Comprehensive allocation process with complete audit trail.	Top-level flow-down process; limited audit trail.	No clear process; many requirements waived at sub level; to be done at prime, rather than by sub.
SPECIAL PROCESSES				
36. Are issues that affect both hardware and software (such as processor type selection) made with inputs from all affected groups?		Yes.		No.
37. Does the contractor have a formal quality assurance process for all aspects of design and manufacturing?	Documented process; proven in multiple use.	Documented process; proven at least once.	Documented process; not proven or minor deficiencies in past use.	No formal process or major deficiencies in past use.
38. Does the contractor's financial management system include an interface with technical management, such that financial deviations caused by technical difficulties can be accurately assigned?		Yes.		No.
39. Does the contractor have a formal technical planning process (including the integration of logistics and manufacturing into the design process)?	Documented process; proven in multiple use.	Documented process; proved at least once.	Documented process; not proven or minor deficiencies.	No formal process or major deficiencies in past use.
40. What is the status of the contractor's technical planning for this effort?	100% complete.	90% complete.	50% complete.	Just initiated.
41. Does the contractor have an adequate integration control process in place?		In place and being used.	In place; not fully used.	Weak or non-existent.

Table O-1 Contractor Capability/Risk Evaluation Guidelist

CAPABILITY	EXCEEDS	MEETS	MARGINAL	POTENTIAL PROBLEM AREA
42. Does the contractor use an effective configuration control process in all areas?		Applied across program with trained personnel.		Not applied to early efforts; done only when Government mandated controls are imposed.
43. Is the Logistics Support Analysis (LSA) process integrated with the remainder of the design process?		LSA integrated with other design efforts.	LSA tracks design effort; done separately.	LSA done as a stand-alone effort.
44. Does the contractor have an effective risk management system?	Comprehensive up front analysis; detailed planning and timely tracking of all risk areas.	Comprehensive up front analysis; planning and tracking of risk areas.	Up front analysis and limited planning of key areas only.	Reaction to failures/problems only.
45. Does the contractor have a comprehensive technical performance tracking system in place?	Documented process proved in multiple use; tracks all requirements; starts with initial analyses. Formal alert reporting to senior management.	Documented process; proven at least once.	Documented process; not proven or minor deficiencies in past use. Only key requirements tracked.	Tracks test results only.
46. Does the contractor have a formal drawing (design) release system in place (scheduled between engineering and manufacturing; review of all drawings by all affected functionals)?	Documented process; proven in multiple use.	Documented process; proven at least once.	Documented process; not proven or minor deficiencies in past use.	No formal process or major deficiencies in past use.
47. Does the contractor have a uniform test reporting system for all testing?		Yes.		No.
48. Does the contractor have a defect control process in use during the design process?		Applied to all aspects of program; focus on effort free design.	Applied to key areas only.	Based on inspection of end products only.
49. Does the contractor have a/an comprehensive failure/anomaly management system?	All program failures investigated; dedicated review group.	All program failures investigated.	Only repeat failures investigated.	No formal process.

Table O-1 Contractor Capability/Risk Evaluation Guidelist

CAPABILITY	EXCEEDS	MEETS	MARGINAL	POTENTIAL PROBLEM AREA
50. Does the contractor ensure a timely close-out to all failure investigations?	Normally within 30 days; formal management notification and tracking of overdue investigations.	Normally within 30 days.	Normally within 60 days.	More than 60 days.
51. Does the contractor implement design corrections in a timely manner?	Aggressive implementation of fixes.	Timely implementation.	Implementation at fixed intervals.	Implementation sporadic.
MANUFACTURING CONSIDERATIONS				
52. Does the contractor have a manufacturing defect tracing system?		Defects rates tracked; timely corrective actions taken.	Defect rates tracked; some lag in correction.	No tracking system.
53. Does the contractor have a comprehensive training and certification process for production workers?	Use of a comprehensive training center to train and update skills.	Formal on-the-job training/certification effort.	Formal on-the-job (OJT) only.	Informal OJT only.
54. Does the contractor have trained manufacturing engineers to work with designers?		Manufacturing engineers part of design team.	Manufacturing engineers review design.	None.
55. Does the contractor have configuration control and inventory control processes for tooling?		Yes.		No.
56. Does the contractor have an effective calibration management process?		Yes.		No.
57. Does the contractor analyze the manufacturing process and have manufacturing standards to accurately determine the labor, material, and resources required to produce the system (expansion of work measurement concept)?		Comprehensive process with validated standards applied to all manufacturing actions.	Formal process using generic standards only.	Informal estimates only.

Table O-1 Contractor Capability/Risk Evaluation Guidelist

CAPABILITY	EXCEEDS	MEETS	MARGINAL	POTENTIAL PROBLEM AREA
58. Does the contractor have an integrated computer-aided design/manufacturing (CAD/CAM) system in place?	Integrated system in place; common data base for system; CAM collects process data.	CAD and CAM systems used; electronic transfer of information; some rework required due to system differences.	CAD and CAM systems used; incompatibilities require manual transfer of information.	Not used.
59. Does the contractor have an on-going process variability reduction effort in place?		Yes.		No.
60. Does the contractor have a process in place to track defective material received from vendors and to take appropriate actions to correct/eliminate the source of defects?		Yes.		No.

APPENDIX P

CONCURRENCY RISK MANAGEMENT

APPENDIX P

CONCURRENCY RISK MANAGEMENT

1. Overview. The use of system development and production concurrency introduces several risk considerations not found in programs which use a sequential development-production process. This Appendix highlights those risk management considerations.

2. Definition of concurrency. Concurrency as used in this Appendix relates to the degree of overlap between a program's development efforts and its production efforts. In this document, the degree of concurrency is based on the relationship between its system level test program (DT&E/IOT&E) and the start of the production commitment. The system test program is measured from the first system level test (e.g., first flight of aircraft) to the end of IOT&E. The production commitment is the time at which the Government either: (1) Awards the first production contract; (2) Exercises an initial production option (where production is an option on a development contract); or (3) Gives approval to begin production on an integral development-production contract. The production commitment normally does not include procurement of long lead items.

If the test program has completed more than 67% of its tests prior to the production commitment, the program can usually be considered to have "low" concurrency. If 33% to 67% completed, the program is moderately concurrent. If less than 33%, the program is highly concurrent. If the production commitment is made before any testing begins, the program is very highly concurrent.

3. Benefits/problems of concurrency. The primary benefit of concurrency is that it can speed the operational deployment of a useful capability. Additionally, there is some evidence that concurrency may decrease the overall cost of the program, since program time is shorter. This shorter time results in less overhead costs being paid, on both the contractor and Government sides. The primary problem area with concurrency is the possibility that extensive retrofits to in-production and fielded systems will have to occur to correct deficiencies. These retrofits are potentially expensive and can delay the operational use of the system. Such retrofits could negate the schedule and (possible) cost advantages of concurrency.

4. Risk areas. The major risk areas are discussed in the following sections. These risk areas are not unique to concurrent programs; however, they play a large role in the success or failure of concurrency.

4.1 Requirements stability. Are the requirements (users', special design, logistics, production) complete? Are the requirements unstable? Are all the defined users in agreement on the users' requirements? What is the stability of the mission need that supports the requirements?

4.2 Technology maturity. Is the needed hardware and software technology available and proven in operational use?

4.3 Funding stability. Is there sufficient consensus for the system to ensure funding through production?

4.4 Testing. Are the necessary resources (people, special test equipment) available to support a realistic test schedule? Are the test objectives clearly defined and measurable? Will production representative equipment be available for IOT&E?

4.5 Production capability. Does the contractor have the necessary facilities in place to meet the planned production schedule?

4.6 Support capabilities. Does the system design require any unusual support features? Are the support requirements defined, funded, and included in the program baseline?

5. Risk handling. Many of the risk handling options addressed in Chapter 4 are applicable to concurrent programs. In addition, the following options may also be useful to concurrent efforts. They focus on methods of controlling the effects that design changes and their retrofit into fielded systems have on the program.

5.1 Minimize retrofit need. The program office must take actions to reduce the possibility of requiring retrofits in the first place. Possible actions include:

(1) Early requirements stability - Requirements instability is one of the largest drivers of design changes. To the extent a firm, stable baseline can be achieved, changes in production can be minimized.

(2) Early below-system level testing - Identify and use opportunities to conduct testing at lower levels (component to subsystem). Such tests can usually be done before system testing and provide insight into many, but not all, design deficiencies.

5.2 Minimize retrofit impact. It is not possible, however, to eliminate the possibility of requiring retrofits. Action must be taken to identify the need for changes and incorporate them in such a manner as to minimize their impacts on the system. Possible actions to do this include:

(1) Ensuring adequate test resources are available - Delays in any test program can have significant consequences for any program. For concurrent programs, the potential consequences are more severe, since more fielded systems will eventually have to be retrofitted. Therefore, taking actions to avoid schedule slips, such

as procuring sufficient test assets (and spares for all assets!), using realistic test realization rates (e.g., accounting for weather delays, facility downtime, etc.), will pay significant dividends. In addition, focusing resources on the test data analysis process can allow more timely discovery of problems.

(2) Rapid corrective actions process - The test process will identify problems with the system; however, testing by itself does not correct the problems. Establishing a dedicated corrective actions process, with on-call engineers, analysis resources, etc., with a focus on rapidly developing and implementing corrective actions to identified problems, is a possible method for early identification of design changes.

(3) Effective transition-to-production process - Pay attention to the process by which design changes are transmitted from the engineering shop to the factory floor. The speed and effectiveness by which this process occurs affects how quickly quality changes are implemented.

(4) Production phasing - In the early stages of the program, examine the production and test schedules. Determine if there are any opportunities to test a risky part of the system prior to that part of the system entering production. If so, schedule the test program to do so. In this way, you may get the opportunity to correct a design deficiency prior to actual production.

(5) Modular design - If retrofits can be expected, then an obvious solution is to design the system for ready changes. Designing the system in modules, such that one part can be changed without affecting another, can minimize the time and expense necessary to make the changes.

5.6 Summary. Concurrency periodically waxes and wanes in favor in the FAA acquisition process. The general problem has been the failure to properly identify and manage the risks inherent in its use. When used, it can achieve significant NAS capability in quicker than normal time. Good up front planning and an eye to potential problem areas will go a long way to effectively using this management tool.

APPENDIX Q

QUANTIFICATION OF RISK PROBABILITIES

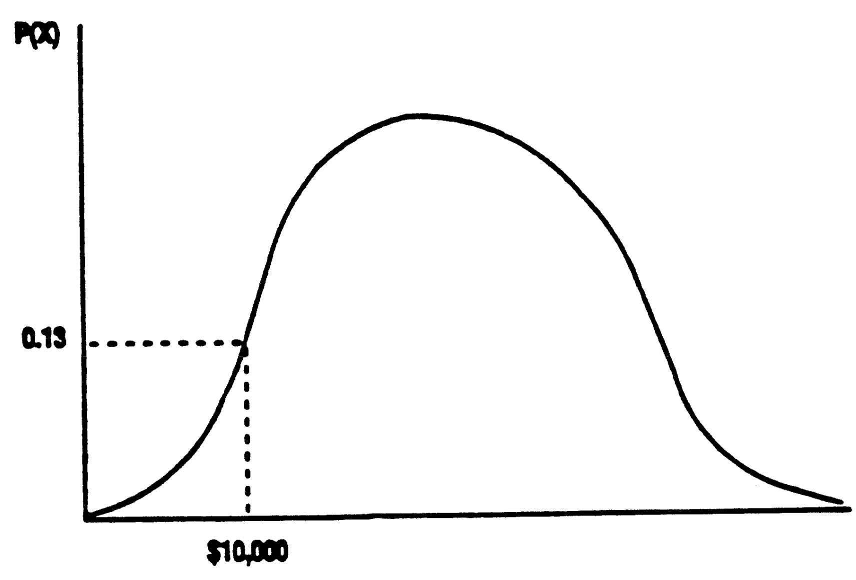
APPENDIX Q

QUANTIFICATION OF RISK PROBABILITIES

1. General. Most risk assessment techniques share a common need, and that is to quantify expert judgment as to the probability of the identified risks. The challenge for the analyst is to obtain expert judgment in the areas of cost, schedule, and technical performance, which is qualitative by nature. Next, the analyst must convert the expert judgment to a quantitative form, so that the results can be depicted in the form of a probability density function (PDF), which serves as input to the various analytical techniques (keep in mind that this is only necessary when a quantified risk probability is required).

A PDF is a smooth line or curve such as shown in Figure Q-1. A PDF of a random variable x is a listing of the various values of x with a corresponding probability associated with each value of the random variable x. For our purposes, x would be a cost, schedule, or performance value. Note that the total area under the curve equals 1. Using Figure Q-1, the random variable x might represent a hardware system cost, the probability of the system costing $10,000 would be 0.13.

Figure Q-1. Probability Distribution Function



There are a number of methods which can be used to convert qualitative judgment into quantitative probability distributions. The remainder of this Appendix will focus on a few of the most popular, practical, and accurate techniques for doing so. The following techniques will be discussed:

- o Direct
- o Diagrammatic
- o Betting
- o Delphi Approach.

2. Direct. The direct method is a relatively simple technique which can be used to obtain subjective probability distributions by asking the expert to assign probabilities to a given range of values. This method of obtaining PDFs is applicable when questions can be phrased to the respondent in such a way that there is no confusion likely to exist in the respondent's mind.

2.1 Application: range and intervals. The application of the direct method is quite simple. The analyst defines a relevant range and discrete intervals for the parameter for which the PDF is to be constructed. For example, the analyst might define the weight range for a piece of equipment to be between 5,000 and 8,000 pounds. The analyst would then break this relevant range down into intervals, say intervals of 500 pounds. The resulting formulation would look as follows:

5000 - 5500 pounds	6501 - 7000 pounds
5501 - 6000 pounds	7001 - 7500 pounds
6001 - 6500 pounds	7501 - 8000 pounds

Given these intervals over the relevant range, the analyst would then query the expert to assign relative probabilities to each range. From this, the form of the PDF could be identified. It is imperative that the axioms of probability not be violated (i.e., the probabilities over the range must sum up to 1). Let us assume the expert assigned the following values:

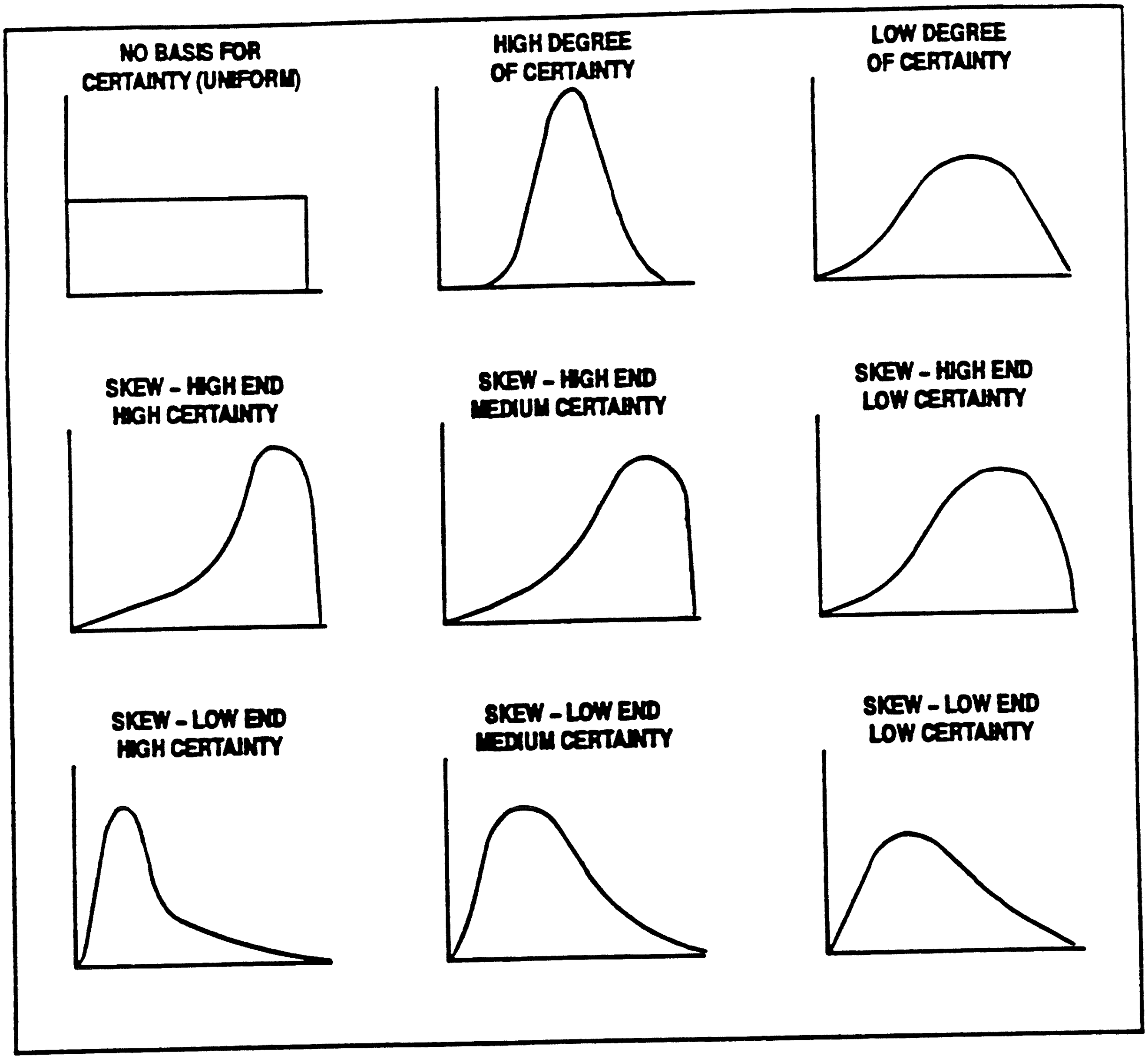
5000 - 5500 pounds	0.05	6501 - 7000 pounds	0.35
5501 - 6000 pounds	0.15	7001 - 7500 pounds	0.10
6001 - 6500 pounds	0.30	7501 - 8000 pounds	0.05

Once these intervals have been obtained, the PDF can be compared to the requirement to determine the probability that the requirement will not be achieved. If the requirement is 6500 pounds or less, then the expert would indicate a 50% chance (probability 0.50) that the system will exceed its weight requirement.

2.2 Application: action and time. The direct method is also applicable when the risk is phrased in terms of an action not being complete by a particular point in time (e.g., what is the probability that the needed technology won't be ready by a required date?).

3. Diagrammatic. The diagrammatic method is a straightforward way of capturing and representing an expert's judgment. In this method, the expert first determines the low, average, and high range for the issue in question. This range could be in the form of a performance parameter (e.g., system weight) or cost/schedule range. The expert is then presented with a range of PDF diagrams, as shown below in Figure Q-2.

Figure Q-2 Sample PDF Shapes



The expert selects the shape of the PDF which is considered to reflect most accurately the parameter in question. Using this method, the analyst can ascertain whether the PDF is symmetric or skewed, the degree of variability, etc. For example, if the expert feels that there is a great amount of risk associated with completing an activity within a certain period of time, a PDF skewed to the right may be selected. Likewise, activities with little risk may be skewed to the left. If the expert feels that each value over the given range is equally likely to occur, a uniform distribution may be most appropriate. The analyst and the expert, working together, can select the PDF which most accurately reflects the item under question. Once the ranges and shape have been selected, the requirement is overlaid and the probability of not achieving that requirement is determined.

4. Betting. One method of phrasing questions to experts in order to obtain probabilities for ranges of values (cost/schedule) states the problem in terms of betting. This method offers the expert a series of bets. In each case, the expert must choose between two bets (the expert is not allowed to refrain from betting).

4.1 Procedure. The expert must choose between a bet with a fixed probability q of winning and 1-q of losing, and a bet dependent on whether or not some event E (a particular program activity duration or cost range) occurs. The bet can be depicted as follows:

Bet 1a - win $A if the event E occurs
- lose $B if event E does not occur

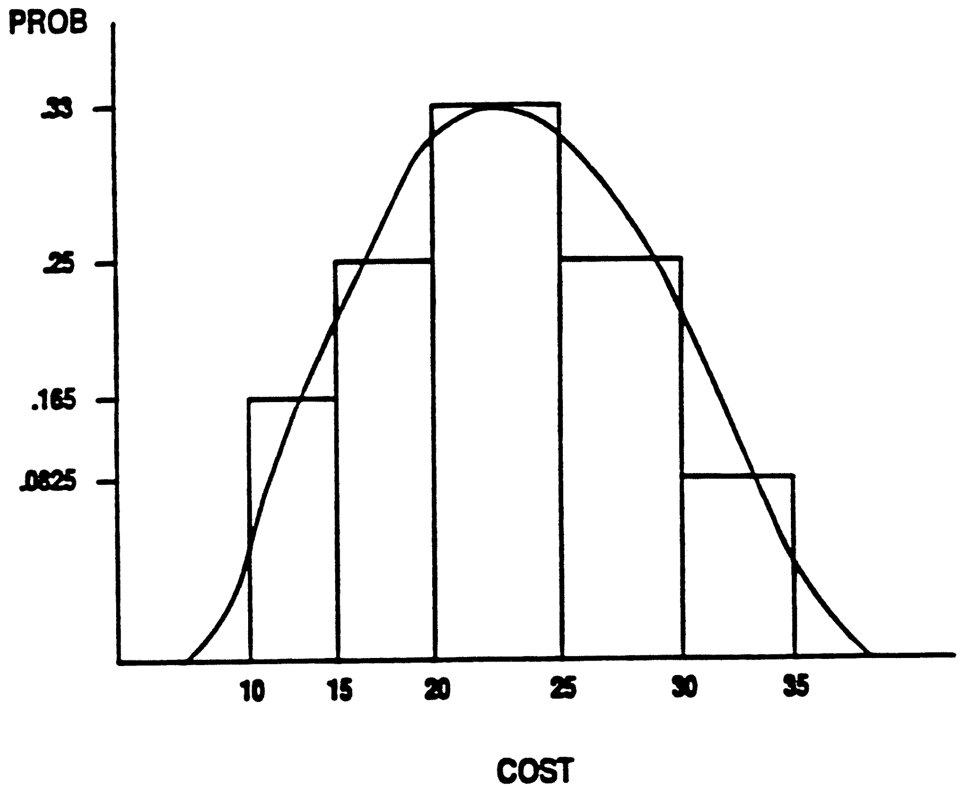
Bet 1b - win $A with probability of q
- lose $B with probability of 1-q

The expected values of bets 1a and 1b to the expert are respectively $Ap + Bp - B$ and $Aq + Bq - B$, where p is the probability of event E occurring. The following inferences may be drawn from the expert's decision: if bet 1a is chosen, $Ap + Bp - B > Aq + Bq - B$, so $p>q$; likewise, if 1b is selected, $p<q$. By repeating the procedure while varying the value of q, the probability of event E can be ascertained. It is the point at which the expert is indifferent between bets 1a and 1b, where $p=q$. The degree of precision is dependent on the number of bets and the incremental changes of the value of q.

A way of avoiding the problem of a large number of bets to obtain p would be to assess the probabilities through the use of direct interrogation, and then to use the betting situation as a check on the assumed probabilities. To complete a PDF, the analyst repeats this procedure over a relevant range of interval values. The analyst then plots the points at the center of the range for each event and smooths in a curve, so that the areas under it equals one, as in Figure Q-3.

4.2 Application. Many people, when questioned one way, are likely to make probability statements that are inconsistent with what they will say when questioned in another equivalent way, especially when they are asked for direct assignment of probabilities. As the number of events increases, so does the difficulty of assigning direct probabilities. Therefore, when this is a problem, the betting method is most appropriate.

Figure Q-3 Fitting a Curve to Expert Judgment



To apply the betting technique, we will select one interval for the relevant range to demonstrate how this method can be used to obtain probability estimates and, hence, PDFs. The bet is established as follows:

Bet 1a - win $10,000 if cost is between $15,000 and $20,000
- lose $5,000 if cost is not between $15,000 and $20,000

Bet 1b - win $10,000 with probability of q
- lose $5,000 with probability of 1-q

The value of q is established initially, and the expert is asked which of the two bets he would take. The value of q is then varied systematically, either increased or decreased. The point at which the expert is indifferent between the two bets (with the associated q value) provides the probability of the cost being between $15,000 and $20,000. This process is repeated for each interval, and the results used to create the PDF associated with the cost of that particular program event.

5. Delphi approach. In many cases, expert judgment does not reside solely with one individual, but is spread among multiple experts. Committee approaches to obtaining a group assessment have been found to contain problems relating to interpersonal pressures to a degree that caused researchers at the Rand Corporation to devise a method known as the Delphi to avoid the pressures. The Delphi approach has become well known in management circles, but is subject to misconception. Too often the term is used to identify a committee or multiple interview process, which do not share the advantages of the Delphi approach.

5.1 Application. The Delphi approach has been extended in recent years to cover a wide variety of types of group interaction. The technique can be used for group estimation, that is, the use of a group of knowledgeable individuals to arrive at an estimate of an uncertain quantity. The quantity can be a cost, a time period associated with an event, or a performance level. The Delphi technique is most appropriate when:

(1) The problem does not lend itself to precise analytical techniques, but can benefit from subjective judgments on a collective basis.

(2) The individuals needed to contribute to the examination of a broad or complex problem have no history of adequate communication and may represent diverse backgrounds with respect to experience or expertise.

(3) More individuals are needed than can effectively interact in a face-to-face exchange.

(4) Time and cost make frequent group meetings infeasible.

(5) The efficiency of face-to-face meetings can be increased by a supplemental group communication process.

(6) Disagreements among individuals are so severe or politically unpalatable that the communication process must be refereed and/or anonymity assured.

(7) The heterogeneity of the participants must be preserved to assure validity of the results, i.e., avoidance of domination by quantity or by strength of personality ("bandwagon effect").

5.2 Use of results. The Delphi approach differs from other methods of obtaining a group opinion, because it physically separates the group's members from one another in order to reduce irrelevant interpersonal influences. Properly carried out, the technique is facilitated by an analyst obtaining each panel member's opinion and each member's reason for the opinion. The analyst then reduces the opinions and reasons to standard statements in order to preserve anonymity. The analyst then shows the panel member the aggregated opinions of the other panel members in statistical terms. The analyst provides each panel member with the reasons justifying the opinions that differ with the member, and requests reevaluation and further substantiation. This iterative feeding back continues until no further substantial change results. At this point, the moderator takes the final individual opinions and computes a set of median values to represent the group opinion. The median value, rather than the average, is used as a central estimate to prevent the estimate from being overly influenced by extreme individual values.

6. Use of historical data. Whenever possible, expert judgment should be augmented with historical data. In many case, past programs have faced similar situations and have an experience base on how they were resolved. Such data can be found through at least two means. First, the experts could be asked to provide such data, based on their experience. Second, the histories of past programs can be reviewed. Only two or three cases may be found, but they would be invaluable in justifying the expert judgments used.

7. Resource requirements. The effort required to conduct expert interviews and generate appropriate PDFs is man-hour intensive. Much time is spent by the analyst with the experts acquiring and quantifying their expertise. The amount of time required to accomplish this task is predicated on the number of PDFs needed (based on the number of activities required as model input and whether cost, schedule, and technical distributions are required). The methods described are basically manual with computer resources not a necessity. As the techniques become more complex and expert support systems to accomplish the tasks are developed, however, the computer resources required will escalate dramatically.

8. Reliability. The reliability of the PDFs obtained through these techniques is affected by a number of factors. Foremost is the degree to which the so-called "expert" is in fact an expert. The better understanding the expert has of the parameter being modeled, the more reliable the resulting PDFs will be. The burden also falls on the analyst to select the technique most appropriate for obtaining PDFs. For example, if expertise resides with more than one expert, a Delphi technique would result in much more reliable PDFs than would a direct method of asking only one expert. Likewise, if the expert has very little understanding of probability concepts, it would be inappropriate to ask him to select a PDF from a visual list of options. Under these circumstances, the betting technique would most likely result in more reliable PDFs. In summary, much of the reliability of the PDFs is predicated on the techniques selected by the analyst for constructing them. It is important, therefore, that the analyst know when each technique is most appropriate, given the unique circumstances of that specific program office.

APPENDIX R

CONTRACTOR RISK MANAGEMENT AND REPORTING REQUIREMENTS

APPENDIX R

CONTRACTOR RISK MANAGEMENT AND REPORTING REQUIREMENTS

1. Introduction. The following sections provide sample Statement of Work paragraphs and contractor report formats for risk management and risk reporting. The program office can use these as a baseline for creating the specific SOW and data items for its use.

2. Statement of Work.

2.1 Continuing Risk Management Activities. The contractor shall conduct continuing risk management activities during the period of the contract. Full consideration shall be given to all factors which could limit technical, schedule, or cost performance of the program. These activities shall identify "low," "moderate," and "high" risk items, track program performance on the risk items, and implement risk abatement procedures as needed. The risk assessment and abatement program tracking, evaluation, and direction will be an integral part of the contractor's system engineering and engineering management procedures. The contractor shall develop, document, and maintain a Risk Management Program Plan (RMPP). The program office may elect to make this plan part of the Systems Engineering Management Plan. The plan shall delineate the methodology to be used to reduce the technical, schedule, and cost risks of the program. Individual risk items will each have a Risk Abatement Plan. Risk Management Status Reports (RMSRs) will provide updated risk assessments and summaries of the current approved individual item Risk Abatement Plans.

2.2 Risk Management Program Plan. The RMPP shall describe all aspects of risk management to include risk identification, assessment, abatement, and control/reporting; the management structure for the risk management program, including responsible management positions; and the assessment methodology and criteria for assigning risk ratings. Each source of risk will be identified as a "risk item," and may be a system, subsystem, or component. The RMPP shall also describe how an iterative risk identification and assessment process is applied at all Contract Work Breakdown Structure levels for each risk item identified. The RMPP shall describe the role of risk management in the program review process, and integrated technical, schedule, and cost monitoring. The plan shall provide the methodology for ensuring that the risk management programs of associate contractors and subcontractors are consistent and compatible with the prime contractor's risk management program. The RMPP shall also describe the process for developing and updating the Risk Management Status Report.

2.3 Risk assessment. A risk assessment shall be conducted to determine the potential impact of each risk item on the overall technical, schedule, and cost performance of the program. The risk assessment shall include a detailed examination of each CWBS area to determine risk items. The risk assessment shall group the risks in the following functional areas: technical (technology, design, engineering {hardware and software}, test, manufacturing, and support), schedule (concurrency), and cost (funding). At a minimum, the total program will be reviewed down to level 4 of the Government-approved CWBS. Each CWBS element will be rated as "low," "moderate," or "high" risk, using criteria established by the contractor and described in the RMPP. The selection of a risk assessment methodology shall be the contractor's choice. The results of the risk assessment shall be incorporated into the RMSR as described in Section 2.5. The risk assessment shall be reviewed on a monthly basis, and the results used to update the report. During the monthly review of risk items, should it be determined that a low risk item has failed to stay with its planned abatement, it shall be identified as "moderate" or "high", and its abatement action reported.

2.4 Risk abatement. The contractor shall develop and implement the appropriate risk abatements for each risk area identified as "moderate" or "high" risk, as identified in the risk assessment. The abatement for each item will be documented in a Risk Abatement Plan and submitted to the Government for review and approval. These plans shall be reviewed and updated as the program progresses and any deviations shall be immediately reported to the Government. A summary of each Risk Abatement Plan shall be included in the RMSR as described in Section 2.5.

2.5 Risk Management Status Report. The contractor shall prepare and submit a monthly RMSR to the Government. The report shall describe each risk item and summarize the corresponding approved abatement procedures and their status. The risk management status reporting process shall provide information on the "moderate" and "high" risk areas of the program, and the status of abatement procedures for each. This shall include a description of the "moderate" and "high" risk areas in terms of actual or potential technical, schedule, and cost problems; their impacts on the program; and the success of abatement procedures. The report shall also demonstrate the explicit coordination of technical, schedule, and costing staff in the assessment and abatement processes, with a common Government-approved CWBS as the basis for each of these different staff activities.

3. Suggested risk plan formats

3.1 Risk Management Program Plan

- Introduction
- Responsibilities
- Risk management process
- Risk identification and assessment
- Development of Risk Abatement Plans
- Risk reporting.

3.2 Risk Abatement Plan

- Description of the risk item, including its CWBS number
- Potential technical, schedule, and cost impacts

- Alternative risk abatement procedures considered and their technical, schedule and cost impacts
- Recommended risk abatement approach
- Criteria and milestones for deciding on contingencies
- Responsible organization(s) and management levels
- Required resources.

3.3 Risk Management Status Report. The report is in three parts:

I. Executive Summary
- Date of the report
- Identification of "moderate" and "high" risk items
- CWBS number for "moderate" or "high" risk item
- Related "moderate" or "high" risk items (by CWBD number). This will identify major systems with the same component, other components, subsystems, or systems with related risks.
- Summary statement of technical, schedule, and cost risks.
- Summary status of the risk items and any risk abatement activities that have been planned or initiated.

II. Risk Assessment
- Identify the "moderate" or "high" risk item.
- Begin each risk item on a new page.
- Provide the CWBS number and risk rating ("moderate" or "high") of the driving risk item. This will be at least down to level 4 of the CWBS, or to as detailed a level as needed to focus on the driving risk item, whether it be a system, subsystem, or component.
- Describe the technical requirement.
- Identify the risk assessment methodology used.

A. Technical risks
- The technical performance requirement for the system, subsystem or component
- The current estimate or tested value of technical performance, compared to the allowable variance of that value
- The expected range for the performance requirements(s) and likelihood of not satisfying the requirement
- The impact of the expected technical performance on the total program.

B. Schedule risks
- The internal milestones and program control milestones threatened with a schedule variance.
- The critical path impacts on the total program must be identified.

C. Cost risks
   - The planned costs, the possible range of projected costs, and the associated cost variances for the risk item
   - When projected costs exceed the planned funding by more than a specified amount, the likelihood of that event occurring.

D. Other factors. Other factors affecting the risk item must be described if they will influence the value of taking alternative actions.

III. Risk Abatement Plan summary. A formal Risk Abatement Plan will be prepared for each item judged to be a "moderate" or "high" risk; and will carry that item's CWBS number, and system, subsystem, or component name. The manner in which the plan summary contained in the RMSR is to address technical, schedule, and cost considerations is summarized as follows.

A. Technical. The measurement parameters by which risk abatement will be quantified will be specified. A set of parameters for assessing the abatement of technical performance risk in the development of an ablation layer on an interceptor are presented as an example in the Risk Abatement Plan Summary of Figure R-1.

B. Schedule. Dates must be specified for the internal milestones at which significant analysis, simulation, test, or other events relating to that item's risk abatement must occur.

C. Cost. Acceptable cost expenditure profiles.

D. Contingency plans
   - For each "moderate" and "high" risk area, the approved contingency plans, which are to be executed if internal milestones are violated, are to be summarized.
   - The approved contingency plans are also to be presented in a one-page format as shown in Figure R-1 with supporting attachments. Each contingency plan must include a description of the problem; the projected technical performance, schedule, and cost; the specific abatement plan tasks; and the impacts on the rest of the program. Any "moderate" or "high" risk item in the contingency plan must be identified and treated the same as the original risk areas in the program.

Figure F-1 Sample Risk Abatement Plan Summary

RISK ABATEMENT PLAN SUMMARY
(Example)

Date: xx/xx/xx

WBS: 42-34-7 Risk Item: Ablation Layer

Current Risk Rating: Moderate

Description of the Problem

The high temperature of the ablation layer on the nose cone of the interceptor is critical for successful performance of maximum altitude intercept. The required operating temperature is 4800 deg. C. The current achieved level is 3500 deg. C. There is a 50% likelihood of not achieving the required technical performance with the baseline approach of using Formula A. If that approach fails at the end of the planned concept test series and there is no alternative development in parallel, there will be a delay of one year, and a development cost increase of xx dollars. In addition, the next best alternative, Formula B, will increase manufacturing costs by yy dollars, and extend the program by yy months.

Abatement Plan

- Conduct parallel development of filament/ceramic Formulas A and B.
- Improve the manufacturing process for Formula B.
- Perform the following development and test profile:
  - Step 1, Jan 92, 3700 deg C, Formula A - successful
  - Step 2, Feb 92, 3700 deg C, Formula B - successful
  - Step 3, Aug 92, 3900 deg C, Formula A
  - Step 4, Sep 92, 3900 deg C, Formula B
  - Step 5, Oct 92, manufacturing improvement test for Formula B, to be conducted only if step 3 is unsuccessful
  - Step 6, Feb 93, 4000 deg C, coolant system for Formula A system
  - Step 7, July 93, 4400 deg C, Formula B
  - Step 8, Oct 93, 4400 deg C, Formula A
  - Step 9, Nov 93, 4800 deg C, Formula B with coolant system
  - Step 10, Jan 94, 4800 deg C, Formula A with coolant system

  Note that if Formula A fails at steps 3, 6, 8 or 10, Formula B will be selected. The manufacturing test for Formula B will be reinstated whenever A fails.

Projected Abatement Results

- Parallel development of B will cost zz-vv dollars from this date forward. The range of expenditures and the associated likelihood is shown in Figure aa (similar to Figure 3d). The likelihood of remaining within ww dollars is 80%.
- Total program cost increase will be ww dollars, assuming expected improvements in manufacturing of Formula B. Less than 10% likelihood of failure in achieving manufacturing improvement.
- Program delays will be no more than 3 months, with a likelihood of 90%.

APPENDIX S

SAMPLE ACQUISITION RISK MANAGEMENT PLAN

This appendix to the FAA Acquisition Risk Management Guide (FARM-Guide) contains a sample Risk Management Plan which was developed using the FARM-Guide, itself. The actual sample plan appears on pages S-3 through S-28. A sample of some of the structured 'worksheets' used in creating the sample plan appear on pages S-29 through S-43. The producers of this sample plan chose not to include the 'worksheets' as an appendix to their plan, or supply other supporting appendices. The 'worksheets' provide a structured approach to producing the lowest level evaluation of a program or product, and a place to begin in creating a bottom-up assessment. Worksheets help a developer to not overlook some detail that may prove to be critical at a later date. The worksheets provided are simple in nature, and should likely be expanded in general, and of course tailored for any given program. For this program one set of five were used, and simply replicated for software and integration analyses. All of the factors were not addressed in each topical area, thus supporting the need to reassess the details on the worksheets themselves. Regardless, it is a good place to start when conducting an analysis.

Other plans have included, as appendices, worksheets, bibliographies, lists of acronyms and unique terms, detailed cost analyses and chronological files. It is a convenient place to 'file' them for future use and as a turnover file, should the Program Manager change, or a service audit occur in the future. Again, remember that FARM-Guide is a 'guide,' and that final employment of it is the Program Manager's (PM) call. How much to include in a 'plan' depends on the complexity and scope of the product or system. It does provide a structure to follow, thereby satisfying some of the concerns of GAO, OST and FAA oversight groups.

Operational and Supportability Implementation System

(OASIS)

Risk Management Plan

(DRAFT)

25 April 1994

EXECUTIVE SUMMARY

The Operational and Supportability Implementation System (OASIS) project which is designed to replace aging automated flight service station (AFSS) equipment will be implemented in two phases: Phase 1A will replace M1FC hardware components with a personal computer (PC) based local area network (LAN) system increase AFSS specialist capability, and provide an integrated weather graphics capability. Phase 1B is a software upgrade to the Phase 1A architecture. The OASIS Project Manager will use the Government management system (FAA Order 1810.1F, Acquisition Policy) to manage and control the project with managerial and technical support being furnished by the Matrix Management Team. OASIS contract award is planned for June, 1995 and first site delivery in 1996. The Project Manager is the Risk Manager with the responsibility for maintaining and implementing this plan and for supervising the execution of the contractor's Risk Management Plan.

In keeping with the Draft Risk Management Guide, risks have been identified in four areas: Overall Program Risks, Hardware Risks, Software Risks, and Integration Risks. Risks have been identified and evaluated through a review of project documents and interviews with project experts. An initial risk Watch List (Figure 1, Risk Summary) has been developed which will serve as the basis for action item tracking by the Project Manager. As the project matures, this plan and its supporting Watch List will be updated and revised.

Risks are placed in one of three categories: High, Moderate, and Low. Initial analysis has identified no High Risk elements to this project. However, three items are in the Moderate Risk category: Pre-Award Schedule, Phase 1B FSDPS software modification, and the Test Program. The Pre-Award Schedule is considered Moderate primarily because of the lack of a coordinated FAA-Congressional acquisition strategy. The Acquisition Plan states that Phase 1B implementation will require FSDPS software changes. Phase 1B software development is a Moderate Risk because of the need for the contractor to understand the FSDPS code and supporting documentation. The Test Program is a Moderate Risk element because of the lead time for the Technical Center to develop an updated Master Test and Evaluation Plan based on revisions to the System Specifications which have been made since the Master Test and Evaluation Plan was approved; and, the time necessary to coordinate the test program with Systems Engineering and integrate the Contractor's Test Program. Several Low Risk elements were also identified and are summarized in Figure 1.

Risk Area	Risk	Probability of Occurance	Impact of Occurance	Mitigating Measures
Overall Program	Pre-Award Schedule	Moderate	High	Coordinated FAA-Congress Acquisition Strategy
	Post-Award Schedule	Low	Low/High	Management Attention
	COTS Congiruation	Low	Low/Moderate	Funding Profile
	Contractor Performance	Low	Low/High	Pre-Award Qualification Post-Award Oversight
	Site Transition	Low	Low	Site Transition Plans
Hardware	Fit and Form	Low	Low	Consoles May be Modified
	RAM Data	Low	Low	RFP Requires Data Audit Trail
	COTS Life-Cycle	Low	Low	Next Generation Program
	Sole-Source Repair Parts	Low	Low	NAILS
Software	FSDPS Interface	Low	Low	HARP Program Experience Programmable Interface
	Phase 1B FSDPS SW Changes	Moderate	High	Government ownership of developed code
	COTS SW Integration	Low	Moderate	Market Surveys
Integration	Testing	Moderate	High	Timely Test Plan Development and Coordination
	Training	Low	Moderate	Fast Track Approval of Training Program for OT&E

Figure 1. Risk Summary

Because the OASIS project management team recognizes the importance of the moderate risk elements and are actively pursuing courses of action which should reduce the risk of these elements and because the preponderance of identified potential risk areas is low, the overall risk assessment for this program is Low. However, if the three Moderate Risk elements are not successfully resolved shortly, they could cause the overall risk assessment to change as they each have the potential to seriously delay the project.

1. PART 1 - DESCRIPTION

1.1 Mission

1.1.1 Mission Statement

The mission of the Federal Aviation Administration is to provide safe and efficient movement and control within the National Airspace System (NAS). One element of this mission is to provide airmen with access to weather and notice-to-airmen (NOTAM) information for flight plan filing activities and to accept, file, open and close flight plans. The automated flight service stations (AFSSs) provides pilots with this access plus flight plan filing capabilities.

1.1.2 Mission Need

The OASIS mission need is to replace aging AFSS equipment to eliminate the logistical supportability concerns and rectify present operational deficiencies and unmet Flight Service Automation System (FSAS) requirements.

1.2 SYSTEM

1.2.1 System Description

The OASIS project will resolve the logistics supportability and operational deficiency concerns with the AFSS flight service portion of the FSAS. The OASIS project will be implemented in two phases: Phase 1A will accomplish three objectives: (a) replace the M1FC keyboards, displays, and computer hardware at 61 AFSSs with a Personal Computer (PC) - Based Local Area Network (LAN) system, thereby eliminating the logistics concerns; (b) provide increased functionality to the AFSS specialist in areas that do not impact the FSDPS software; and (c) provide an integrated weather graphics capability. Phase 1B, deployed as a software upgrade only to the Phase 1A architecture, will implement additional functionality to the AFSS specialist in areas that may require changes to the FSDPS software, or require more time for software development.

1.2.2 Key Functions

OASIS will provide all the functions currently performed by the M1FC in addition to the improved functionality required by the System Specification. Details of all of these functions may be found in the OASIS System Specifications.

OASIS will continue to provide the following M1FC functions: Weather and NOTAM Data Handling, Flow Control Data and Military Data, Pilot Briefing, Flight Assistance of Flight Plan Data, Mass Weather Dissemination, Flight Data Handling, System Monitoring, Administrative Message Processing, Communications, and System Recording.

The following functions, not now performed by the M1FC will be provided by OASIS: Tiered Security System, Off-Site Access, Upload/Download Capability, and Graphics and Word Processing.

1.3 REQUIRED OPERATIONAL CHARACTERISTICS

OASIS will serve as the principal information processing and retrieval source for the flight service specialist and the pilot. The System Specifications and the Statement of Work detail the specific operational characteristics.

1.4 REQUIRED TECHNICAL CHARACTERISTICS

The required technical characteristics are defined in the OASIS System Specifications. These technical characteristics include the requirement for OASIS to be easily adaptable to upgrades in technology and will incorporate COTS hardware and software to the extent possible.

2. PART 2 - PROGRAM SUMMARY

2.1 SUMMARY REQUIREMENTS

Requirements in the OASIS program have been defined early in the program through the Mission Need Statement (MNS), GWDS MNS, and OASIS Operational Requirement Document. The MNSs are updated as the requirements change and are reviewed prior to each acquisition milestone, as required by FAA Order 1810.1F, Acquisition Policy. OASIS requirements have been validated and are considered stable.

In addition to the mission need of replace aging AFSS equipment to eliminate the logistical supportability concerns and rectify present operational deficiencies and unmet FSAS requirements, there exists a need for incorporating the functionality identified in the GWDS MNS to acquire a fully integrated weather graphics system. GWDS will meet Air Traffic needs of information timeliness, consistency, and accuracy, and will be tailored to facilitate the operations and decision-making process.

Further details of the FSAS OASIS and FSAS NextGen mission needs are identified in the FSAS Computer Replacement MNS (NPI #0014). For the GWDS, mission need details are identified in the National Graphic Weather Display System (GWDS) MNS (NPI #0074).

2.2 MANAGEMENT

The project manager will use the Government management system as defined in FAA Order 1810.1F, Acquisition Policy, including conducting a quality assurance program, a configuration management program, procurement readiness reviews (PRRs), program reviews, testing, national airspace integrated logistic support (NAILS) procedures, contractor conducted system requirements review (SRR) and test readiness review (TRR), and analysis of contract deliverables.

Project office management and technical support is provided through the Matrix Management Team and technical assistance contracts which can be adjusted to provide additional support.

The principal management tool used for implementing this plan and managing risk is the Watch List. The Project Manager will maintain the Watch List as a list of on-going critical action items and will review status and actions taken at each management review. The Watch List and this plan will be updated after any review during which additional elements of risk are identified.

2.3 INTEGRATED SCHEDULE

The requirement is to achieve first site delivery in 1996. The period of performance of the development contract will commence upon contract award, planned for June of 1994. The deliveries of the production systems will begin two months after execution of the production/deployment contract, scheduled for June of 1995, and will continue through last site deployment. The deployment of Phase 1B will begin in August, 1997. Once the contractor's schedule is integrated into the Government schedule, analysis of the critical path will determine whether additional barriers to meeting schedule exist. On-going analysis of work completed vis-a-vis the schedule is essential to the detection of critical path alterations.

3. PART 3 - APPROACH TO RISK MANAGEMENT

This section discusses the Risk Manager's approach to risk management. It includes definitions of terms used in the plan,
a discussion of the program structure (two phased procurement), techniques applied in identifying and assessing risks, and plan implementation. Because the Risk Management Plan is a living document, the Risk Manager will update the plan at appropriate times during the life of the program. This edition of the plan places emphasis on events leading up to contract award. As identified risks are overcome and new risks are identified, changes are generated to this plan. Additionally, when a prime contractor is selected, elements of his risk management plan may be incorporated into the updated edition of this plan to provide a course to follow for the next program period.

3.1 DEFINITIONS

- Cost and Schedule Risk: Cost and schedule growth is the difference between the estimated project cost and schedule and the actual cost and schedule.

- Expert Interviews: Identification of appropriate experts and methodically questioning them about the risks in their area of expertise as related to the project.

- Plan Evaluation: evaluation of program plans and technical documents for contradictions and voids.

- Programmatic Risk: Those risks which include obtaining and using applicable resources and activities which may be outside of the project's control, but can affect the project's direction.

- Low Risk: Has little potential to cause disruption of schedule, increase in cost, or degradation of performance. Normal contractor effort and normal government monitoring will probably be able to overcome difficulties.

- Moderate Risk: Can potentially cause some disruption of schedule, increase in cost, or degradation of performance. However, special contractor emphasis and close government monitoring will probably be able to overcome difficulties.

- High Risk: Likely to cause significant serious disruption of schedule, increase in cost, or degradation of performance even with special contractor emphasis and close government monitoring.

- Supportability Risk: The risk associated with fielding and maintaining systems which are currently being developed or have been developed and are being deployed.

- Technical Risk: The risk associated with evolving a new design to provide a greater level of performance than previously demonstrated, or the same or a lesser level of performance subject to some new constraints.

- Watch List: a work sheet managers use for recording risk management progress.

3.2 STRUCTURE

The program structure was developed using information provided by the Cost-Benefit Analysis and the Independent Cost Estimate conducted by FAA Systems Engineering branch. The Cost-Benefit Analysis determined that the purchase of OASIS was preferable to leasing and the incorporation of the Graphic Weather Display System (GWDS) function into OASIS was economically preferable to the acquisition of two separate systems.

The OASIS program is planned to be implemented in two phases each of which will have a development and a production element:

- Phase 1A will accomplish three objectives: (a) replace the M1FC keyboards, displays, and computer hardware at 61 AFSSs with a PC-based LAN system, thereby eliminating the logistics concerns at the AFSS; (b) provide increased functionality to the AFSS specialist in areas that do not impact the FSDPS software; and (c) provide an integrated weather graphics capability (GWDS).

- Phase 1B, deployed as a software upgrade only to the Phase 1A architecture, will implement additional functionality to the AFSS specialist in areas that require changes to the FSDPS software, or require more time for software development.

- The development element will be performed under a cost reimbursable contract which will be awarded after full and open competition. The production portion of each contract phase will be accomplished by the development contractor under a sole-source follow-on contract after successful development has been demonstrated.

3.3 Methods Overview

In identifying and evaluating OASIS risks, heavy reliance was placed on the latest approved project documentation. As changes in this documentation occurs, this plan will be updated to reflect the impact of these changes.

3.3.1 TECHNIQUES APPLIED

Identification and evaluation of risk factors was accomplished by using a combination of the expert interviews and plan evaluation techniques. Project Office and operational experts were interviewed and the Project Acquisition Plan, Draft Request for Procurement Authority, Draft System Specifications and Draft Statement of Work were evaluated for risk. The FAA Acquisition Risk Management Guide, Chapters 4, 5, and 6, and Appendices A, G, J, K, L, M, and P were employed extensively in producing this OASIS Risk Management Plan. Using these techniques, a Watch List has been prepared and an evaluation of risk for each element on the Watch List has been developed.

3.3.2. IMPLEMENTATION

The Project Manager is the Risk Manager and the implementation of this plan is his responsibility. However, the management of project risk is a responsibility shared by both the government and the contractor. In forming his contract performance team, the Project Manager will establish the agenda for risk management which will include tracking risks identified in this plan and placed on the Watch List, a mechanism for flagging and bringing potential risks under management review as they are identified, and a procedure for determining when a previously identified risk no longer exists. Standard management techniques such as program reviews, on-site visits, evaluations of contractor deliverables, etc., will be used to monitor items on the Watch List.

Because project risk is a commodity shared between the government and the contractor, each offeror will be required to address risk with his proposal, the evaluation of the offeror's identification and treatment of risk becomes an award factor. Chapter 7 of the FAA Acquisition Risk Management Guide will be used as guidance in this area. This not only allows the FAA to evaluate how the offerors view project risk, but also serves to either validate the risks already identified or demonstrate that the risks earlier identified do not exist or have been successfully mitigated and may be removed from the Watch List. After contract award FAA will update this plan and include appropriate contractor identified risks in its Watch List.

Management and technical analysis, including analysis of contractor's deliverables will continue during the life of the project to identify additional risks. Language has been included in the RFP to notify the contractor that their deliverables will be used for this purpose.

4. PART 4 - APPLICATION

The FAA Acquisition Risk Management Guide defines four risk areas which should be addressed in a risk management plan: Risk Assessment for Overall Program, Risk Assessment for Hardware, Risk Assessment for Software, and Risk Assessment for Integration. Additionally, within each risk area the format is identical.

4.1 Overall Program

4.1.1 RISK ASSESSMENT FOR OVERALL PROGRAM

This section contains risks which have an overall impact on the OASIS program such as the ability to accomplish the acquisition on time and within budget, the feasibility of the acquisition strategy (e.g. COTS), contractor performance risks, and system transition risks.

4.1.1.1 Risk Identification

The following initial overall program risks were identified by reviewing the program plans and interviewing project experts:

- The Acquisition Plan defines Schedule as the "largest constraint". Since replacement of AFSS "hardware (Phase 1A) must begin in 1996 to resolve immediate supportability concerns", the results of a slip in the Phase 1A schedule can be serious as it may result in late delivery of systems thus causing operational problems at the AFSSs due to the inability to maintain old equipment. Phase 1B schedule risk will be assessed when the contractor's proposed schedule is received. Schedule Risk is divided into two segments for this edition of the Risk Management Plan: pre-contract award activities and post-contract award activities.

    -- Pre-Award Schedule Risk, includes all of the activities performed by the matrix organization in support of the acquisition process and the adequacy of funding for to support procurement. Acquisition activities are scheduled to provide the necessary information at Key Decision Points (KDP 1, KDP 2, etc.). If any acquisition support activity cannot complete its tasks by the scheduled KDP, the acquisition program schedule is at risk. Many of the events which must occur are beyond the capability of FAA to control such as congressional briefings, Departmental approvals, etc. An early-on schedule shortfall can seriously impact the capability to meet the scheduled contract award date. Currently, there are neither FY 1995 funds in the budget nor authorization to spend funds if they become available.

    -- Post Award Schedule Risk, it is expected that during the proposal evaluation phase each offeror will have produced a schedule which meets the FAA requirement. Each offeror will also been required to identify project risks and offer plans to mitigate those risks. Government analysis must assess risks to the government based on their review of the schedule of the successful offeror.

- The Government does not control the configuration of COTS items. There is no guarantee that systems delivered at different times in the program will have the same configuration or that original commercial suppliers will continue to manufacture spares and repair parts to fit the OASIS configuration.

- Because of the heavy dependency on COTS/NDI, the procurement is open to a large range of potential vendors, both primary and secondary source suppliers. This could result in the selection of a vendor lacking in the economic strength to finance a program of this magnitude over the entire program period.

- The AFSS must continue to operate during the commissioning of OASIS and the decommissioning of M1FC/IGWDS. Without careful site transition planning, service interruptions could occur.

4.1.1.2 Risk Quantification

Risk quantification is not used to evaluate risk for this project. In the spectrum of the risk management process, the weakest area at present is that of "quantifying expert judgment". Transitioning from the English language statement of experts to the mathematical expressions required by the analytical tools is done inconsistently.

Additionally, because of the scope of this procurement and the dependence on COTS/NDI, the use of probability and statistical analysis is not useful.

4.1.1.3 (Reserved)

4.1.2 RISK ANALYSIS

Schedule Risk:

The project schedule is the major tool used to track and control schedule risk. While emphasis is placed on the critical path, any element in the schedule has the potential to become a risk factor. The points discussed below are the initial events which have been placed on the Watch List. On-going schedule analysis will be performed by the project management team through the life of the project to monitor these initial events and to add new events as they are identified as risks to the project.

- Pre-Award Schedule Risk, the Acquisition Plan details the acquisition streamlining measures which have been undertaken to insure on-time RFP release. A risk element remains, however, because there is no coordinated FAA/Congressional procurement strategy. The issue is whether congress will approve the inclusion of the graphics capability in OASIS. Without this coordinated procurement strategy, funding authorization will not be provided even if funds are identified in the budget. OST KDP 3 approval is dependent on this unified strategy. Because the possibility exists that congress will not approve incorporating graphics into OASIS, two separate sets of specifications have been prepared (one with graphics and one without) to minimize the time getting the procurement out once a final decision has been made. Until the questions of procurement strategy and funding authorization are decided, the Pre-Award Schedule Risk is rated Moderate and will remain on the Watch List until contract award.

- Post-Award Schedule Risk, the development contract for both Phases will be awarded based on full and open competition while the production contract will be a sole source award once the contractor has proven his development. The program schedule calls for OASIS Phase 1A first site delivery in 1996. Delivery in 1996 is necessary to overcome the key requirement to replace aging equipment which has become non-supportable. Delivery of OASIS Phase 1A with COTS hardware and minimal software development will meet supportability concerns and allow for additional time for Phase 1B development. Additionally, the Acquisition Plan calls for consideration of incentives to shorten the development and deployment of Phase 1B capabilities without jeopardizing the requirements of Phase 1A. Schedule Risk is Low because of the careful up-front planning including providing industry with draft specifications, a draft RFP and the continued participation of industry up to the issuance of a final RFP. The Post-Award Schedule Risk is Low, but will be retained on the Watch List until project completion. Government analysis of the contractor's schedule may identify specific schedule risks which will be added to an updated RMP and the Watch List.

COTS Configuration Risk:

Because of the volatility of the commercial computer industry, COTS hardware and software may evolve during the procurement period. While the Phase 1A development contract calls for procurement of a limited amount of COTS hardware and software, the production contract could be affected if the funding profile for this project is allowed to stretch out in time. Currently, this risk is mitigated by the funding profile which allows the hardware and software for Phase 1A be purchased in a short span of time. The COTS Configuration Risk is Low.

Contractor Performance Risk:

Because of the heavy reliance on COTS hardware and software the Contractor Performance Risk is Low. However, these same project characteristics make it an attractive marketing target for a wide-range of competitors including small, undercapitalized companies. Some of these small companies could present a performance risk if they run into financial or personnel problems during the performance period.

Site Transition Risk:

OASIS will replace equipment now operating in the 61 AFSSs. There will be a period at each AFSS when the OASIS equipment is installed and the old M1FC/IGWDS is decommissioned and removed. The operation of the AFSS will continue during site transition. Improper planning or inefficient execution of the plan could disrupt on-going operations at the AFSS.

4.1.3 RISK MANAGEMENT

Schedule Risk:

- Pre-Award Schedule Risk:

Because every slip in the project in the pre-award phase normally leads to at least an equal slip in the post-award schedule, every effort will be made to release the RFP on time. Some of the activities which must be accomplished are beyond the capability of FAA to control. However, actions (such as the dual preparation of system specifications) have been taken to mitigate the impact of these potential delays. Acquisition streamlining activities are geared toward reducing the pre-award schedule risk by providing the capability to shorten the source selection process to offset delays incurred in getting the RFP issued. Additionally, offerors with innovative solutions to shortening the Phase 1A development contract schedule to allow for a quicker award of the production contract will be rewarded in the proposal evaluation process. During subsequent schedule analysis, particular attention will be paid to reducing the post-award schedule in order to deploy OASIS on time.

Normal government management procedures will be employed to assure the responsiveness of the matrix management system to meet scheduled milestones.

- Post-Award Schedule Risk:

During the source selection process, offeror's schedules will be evaluated to assess Schedule Risk. After award, a thorough review of the contractor's schedule will be performed on the monthly Cost/Schedule Status Reports (C/SSR) for both Phases 1A and 1B to ensure that the Schedule Risk continues to be low.

An important element in managing Schedule risk is insuring that the government meets its internal deadlines for reviewing and approving contractor documentation. Typically, the DID calls for the government to have a 30-45 day review period. Historically, this review period has not always been met, leading to delays in contractor performance attributable to the government. The OASIS Project Manager will closely monitor the contractor deliverable distribution and review procedures and will provide the necessary resources to insure that replies are received by the required date.

Additionally, Schedule Risk will be included on the Watch List and will remain there during the life of the project to ensure prompt recognition of, and attention to, schedule problems.

COTS Configuration Risk:

- This item will remain on the Watch List until delivery of uniformly configured COTS hardware and software is assured.

Contractor Performance Risk:

- During the proposal evaluation period, special attention will be paid to the financial viability, corporate experience, and management capabilities of offerors. Contractor Performance Risk will be on the Watch List until contract award. After contract award the Government will use the Government Management System as defined in FAA Order 1810.1f, Acquisition Policy.

Transition Risk:

- Transition Risk is mitigated by the coordination experience gained by the Project Office in the deployment and commissioning of M1FC at these same sites. Additionally, the internal system redundancy allows for system coverage of individual AFSS positions or of the entire AFSS should that be necessary. The contractor is required to provide a Site Installation and Checkout Plan for each of the 61 AFSSs for Government approval prior to beginning site installation. To assist the contractor, FAA will conduct joint (program office/region/contractor) site surveys and project briefings. During the Government approval process operational transition issues will be identified and an Operational Transition Plan will be developed to insure continuity of service during the installation and checkout period. Transition Risk is Low and its continuation on the Watch List will be determined by the review of Site Installation and Checkout Plans for any indication of technical, schedule or operational risk. Individual site installation activities may be placed on the Watch List as the planning and integration efforts at each site evolve.

4.1.3.1 Risk Reduction Milestones

The Risk Manager will use the following project milestones to review progress in risk mitigation activities and as opportunities to identify additional risks.

- Procurement Readiness Reviews (PRR)

- Design Readiness Reviews (DRR)

- Quarterly Program Management Reviews

- System Requirements Review (SRR)

- Test Readiness Review (TRR)

- Technical Interchange Meetings (TIMS)

- Functional Configuration Audits (FCA)

- Physical Configuration Audits (PCA)

- Factory Acceptance Test (FAT)

- Contractor Deliverable Reviews

- Developmental Test and Evaluation (DT&E)

- Operational Test and Evaluation (OT&E)

- Acquisition Plan required program milestones

4.1.3.2 Reserved

4.1.3.3 Risk Budgeting

- .The Acquisition Plan states that a contractor will be selected to develop and integrate the system and the winner of the development competition will be awarded a sole-source production contract. The Acquisition Plan will be updated to explain measures which insure that the contractor with the best and most cost effective development solution can provide the best price for the production and deployment phase.

4.1.3.4 Contingency Planning

- A plan has been developed to produce two separate system specifications to accommodate the congressional decision regarding the inclusion of graphics in OASIS.

- Operational contingency plans may be developed if contractor Installation and Checkout Plans identify any possibility of an interruption in site service during transition.

- No funds have been identified for risk contingencies.

4.2.1 RISK ASSESSMENT FOR HARDWARE

Emphasis has been placed on procuring COTS hardware to replace AFSS console components. Analysis of the state-of-the- art shows that all hardware requirements may be satisfied without exceeding current technology.

4.2.1.1 Risk Identification

- COTS Hardware must conform to form and fit as replacement components for existing terminal equipment.

- COTS Reliability and Maintainability data from vendors is normally not provided.

- COTS computer hardware has a nominal life cycle of 3-5 years.

- Repair parts may be sole source.

4.2.2 RISK ANALYSIS

- Form and fit of replacement components into the existing AFSS operator consoles is a Low Risk element. The FAA is prepared to allow the contractor to remove consoles for modification for hardware installation should that become necessary. However, it is expected that all offerors will make a best effort to meet form and fit without AFSS disruption in order to score high on their technical proposal evaluation. This element is on the Watch List because of the possibility of impacting operations during transition. The proposal evaluation plan will emphasize this factor.

- The RFP Statement of Work requires that offerors provide the methodology used to determine reliability and maintainability. This proof can be through testing, vendor documentation, or computer modeling. The RFP will require offerors to describe and validate the methodology used to derive this data. This is a Low Risk element which is on the Watch List and expected to remain there through OT&E.

- The Next Generation Program is expected to replace most OASIS components beginning in 3-5 years. Delays in that program could cause OASIS equipment to operate beyond the normal life-cycle of the COTS hardware. This presents no risk to the OASIS project, but is does present a risk to the FAA. If the Next Generation Program slips, the life cycle costs of OASIS will begin to climb due to increased maintenance costs. In addition, because of the rapid evolution in COTS hardware, replacement parts/components may not be available beyond the expected life cycle. The NAILS management team will address this risk element in the RFP requirement for an integrated support plan.

- Particular attention will be paid to each offeror's proposal in regard to the maintenance plan proposed and the availability of repair parts for hardware components. This is a Low Risk element and is on the Watch List.

4.2.3 RISK MANAGEMENT

Proposal evaluation will ensure that hardware fit and form and the reliability and maintainability factors are adequate prior to contract award. The concern about the useful life of the OASIS equipment will be of concern to the FAA until the equipment is eventually replaced. The NAILS manager will closely monitor FAA activities related to fielding the Next Generation equipment and will be prepared to develop contingency plans to keep OASIS in service beyond the expected hardware life cycle. The OASIS Risk Manager will use the following project milestones as opportunities to identify additional hardware risks.

4.2.3.1 Risk Reduction Milestones

- Procurement Readiness Reviews (PRR)
- Design Readiness Reviews (DRR)
- Quarterly Program Management Reviews
- System Requirements Review (SRR)
- Test Readiness Review (TRR)
- Technical Interchange Meetings (TIMS)
- Functional Configuration Audits (FCA)
- Physical Configuration Audits (PCA)
- Factory Acceptance Test (FAT)
- Contractor Deliverable Reviews
- Developmental Test and Evaluation (DT&E)
- Operational Test and Evaluation (OT&E)
- Acquisition Plan required program milestones

4.2.3.2 Reserved

4.2.3.3 Risk Budgeting

- No separate funds have been identified for hardware risk management.

4.2.3.4 Contingency Planning

- Site transition plans will include operational plans to account for contingencies arising from integration and test activities.

4.3.1 RISK ASSESSMENT FOR SOFTWARE

Software development for Phase 1A consists of interfacing with the FSDPS, providing a LAN and graphic weather display capability, and other software development which increases functionality without impacting FSDPS software. Phase 1B will implement additional functionality which require changes to the FSDPS software, or require more time for software development.

OASIS software development has been identified and modeled both in SASET and the Externals Counting Method (ESLOC).

SASET is a parametric cost estimation model which provides both labor requirements and schedule for software development and integration. The number of lines of code, complexities and other parameters were provided by FAA systems engineers. OASIS software requirements include 34,700 new and 5,000 modified lines of code for improved OASIS capabilities and the integration of COTS packages and 45,000 lines of FSDPS code modifications.

The Externals Counting Method of software estimation was used in the Independent Cost Estimate to derive the requirement for software development of 34,700 equivalent source lines of code (ESLOC) and 5,000 modified ESLOC. An additional 40,000 lines of FSDPS code were identified as needing minor modification to account for system modifications between the time of contract award and OT&T.

4.3.1.1 Risk Identification

Phase 1A Software Risk Identification.

- Development of Software to allow the network server to communicate with the FSDPS is the key development element to the project phase 1A. The majority of the 34,700 new and 5,000 modified lines of code for improved OASIS capabilities and the integration of COTS will be developed in this phase. The ability to access the FSDPS database using a COTS, PC based system at the AFSS was proven when Hurricane Andrew destroyed the Tamiami AFSS and the Hurricane Andrew Hardware Replacement Program (HAHRP) was initiated. For HAHRP a COTS, PC based hardware system was developed and integrated at the Tamiami AFSS. In addition to successfully reconstituting the AFSS, HAHRP also served as a risk reduction activity for the OASIS program.

- Risks in using COTS/NDI software:

-- The software may not perform exactly as advertised. COTS programs have been known to run differently depending on the platform. Selection of a COTS package which completely satisfies the specifications is not always possible.

COTS documentation may be poor or insufficient for integration into OASIS.

Resolution of problems may be dependent on third parties, (i.e. COTS vendors/developers).

Phase 1B Risk Identification

- Phase 1B implementation will require FSDPS software changes. The 45,000 lines of FSDPS code modifications to properly handle OASIS capabilities, the additional 40,000 lines of minor code modification for the FSDPS updates to account for FSDPS modifications between contract award and OT&E, and some of the 37,500 new and 5,000 modified lines of code for COTS integration will be developed in Phase 1B. FSDPS software consists of one million lines of proprietary language code now resident on the FSDPS computers.

4.3.2 RISK ANALYSIS

The OASIS SOW requires software development to be accomplished in accordance with (IAW) FAA-STD-026 and that the contractors conduct the appropriate reviews IAW FAA-STD-026 and MIL-STD-1521B. The use of a standardized approach to developing and managing software development is a critical step in minimizing software development risk.

Phase 1A

- The HAHRP program has demonstrated that the OASIS-FSDPS software interface for terminal operation (Phase 1A) is possible. Interface with the FSDPS will use the ADCPP X3.66-1979 protocol.

- The FAA has conducted significant market research to determine the availability of COTS/NDI software that can be used to satisfy OASIS requirements. Six vendors responded with information and possible solutions. Provision of COTS software to satisfy designated requirements is a Low Risk element. Evaluation of the offerors' proposals will determine the best COTS solution and this element will remain on the Watch List until evaluation of proposal insures that COTS/NDI is available to satisfy OASIS requirements.

- Evaluation of the offerors' proposals will identify any risk associated with COTS integration. COTS integration risk is on the Watch List as Low.

Phase 1B

- The requirement for Phase 1B modification of FSDPS software is on the Watch List as a Moderate Risk element because of the inherent difficulties in interpreting the FSDPS documentation and understanding the logic behind the code. The performance of any contractor, other than the original software developer (E-Systems), is at risk in writing modifications to FSDPS code.

- In mitigating future risk to the FAA because of software modifications to the FSDPS software, the RFP specifies that the appropriate standards are to be used and also insures that the government has source code, documentation and necessary data rights.

4.3.3 RISK MANAGEMENT

4.3.3.1 Risk Reduction Milestones

- By using FAA-STD-026, software risks will be reduced and controlled through design reviews, management reviews, technical interchange meetings, acceptance tests, audits, reports, and proper government oversight of the contract and contractor.

- The following issues will be addressed early, beginning with proposal evaluation, and will continue to be addressed throughout the life of the program:

-- Establishment of a formal Software Quality Assurance Program,

-- Use and monitoring of IV&V,

-- Adequacy of the development environment,

-- Appropriateness of the high order language selection,

-- Use of rapid prototyping,

-- Baselining of the software approach,

-- Establishment of the testing philosophy,

-- and, Establishment of the development philosophy.

4.3.3.2 Reserved

4.3.3.3 Risk Budgeting

No funds have been designated for software contingency risks.

4.3.3.4 Contingency Planning

Because the OASIS SOW requires that the contractor upgrade the OASIS software to be consistent with the FSAS software build in operation at the time of OT&E, no operational or transition contingencies are projected. However, the Transition Plan will address potential operational contingencies which may be caused by software.

4.4.1 RISK ASSESSMENT FOR INTEGRATION

4.4.1.1 Risk Identification

Integration, testing, and training are included in this section. Because the current operational communications system will be used, communications are not considered a risk element. The hardware will be integrated into existing operator consoles and any fit or form risks are discussed in the hardware risk area. Each site must identify space for the network server and site specific integration issues, however there is currently no risk to the project attached to this requirement.

- The system specification identifies five system interfaces: FSDPS, Integrated Communications Switching System (ICCS), Automated Surface Observing System (ASOS), Weather Graphics, and Remote Site. Interface Requirements Documents for the FSDPS, the ICCS and ASOS are being developed by Systems Engineering. The Remote Site interface does not require an IRD because the system specifications require the CCITT V.34, Transmission Protocol. The major unknown is whether weather graphics will be provided to OASIS through the Weather and Radar Processor (WARP) system or wether OASIS will access the source data directly. This decision will determine whether WARP will provide the interface or the OASIS contractor must develop a weather graphics interface which would require an IRD from Systems Engineering.

- The test program is driven by two, independently developed test plans: the Technical Center developed Master Test and Evaluation Plan (TEMP) (which has been approved, but must be updated to reflect the National Airspace System (NAS) NAS-SS-1000 Change Proposal (NCP) and the most recent system specifications), and the Contractor's test plan (required by the RFP). The test program will be guided by the TEMP which will test to the requirements of the NAS-SS-1000. The development of the TEMP is dependent on the development and approval of the NCP (developed by Systems Engineering) which will update the NAS-SS-1000 to reflect the new AFSS environment.

- The development and conduct of training for OT&E is very time sensitive. The contractor must develop and the government must approve the training program in a very short time span.

4.4.2 RISK ANALYSIS

- The development of the IRDs is considered a Low Risk. Interfaces will not be included in the Watch List but may be added if technical uncertainties arise or if delays in the development of IRDs occur. Additionally, if weather graphics are to be provided through WARP, the OASIS risk manager must closely track the WARP program for potential impact on OASIS.

- Due to the time necessary for development and coordination of the test program and its supporting documentation, the requirement that the government and contractor programs be compatible, and because every change in the system specifications has the potential to generate a change in the test documentation, testing is considered a Moderate Risk and will be on the Watch List.

- The development and conduct of training is a Low Risk element, but will be on the Watch List because of the criticality of meeting the OT&E schedule.

4.4.3 RISK MANAGEMENT

- The testing program will include risk-driven testing. With this approach, the software engineer must approach the system from a new perspective. This approach is based on identifying the worst things that can go wrong. Risk-driven testing will be conducted in addition to and not in place of all other contractually required testing. It is comprised of the following:

-- The most important events in the system must be determined

-- Any faults that may interfere with the events must be identified and a "fault tree" produced

-- The circumstances under which the software components or segments may be executed must be determined

-- Test cases must be developed to explore these circumstances

4.4.3.1 Risk Reduction Milestones

- Test Readiness Reviews (TRR)

- Technical Interchange Meetings (TIMS)

- Physical Configuration Audits (PCA)

- Factory Acceptance Test (FAT)

- Developmental Test and Evaluation (DT&E)

- Operational Test and Evaluation (OT&E)

4.4.3.2 Reserved

4.4.3.3 Risk Budgeting

- No funds have been identified.

4.4.3.4 Contingency Planning

- Site transition plans will include operational plans to account for contingencies arising from integration and test activities.

5. PART 5 - SUMMARY

OASIS Program risks have been identified in each of the four areas designated by the FAA Risk Management Guide: Overall Program, Hardware, Software, and Integration.

For the Overall Program, five risk elements have been included: Pre-Award Schedule, Post-Award Schedule, COTS Configuration, Contractor Performance, and Site Transition. In the Hardware area there are four risk elements: Fit and Form, RAM Data, COTS Life-Cycle, and Sole Source Repair Parts. The initial software development risks are: FSDPS Interface, Phase 1B FSDPS Software Changes and COTS Software. Two Integration risk areas have been identified: Testing and Training.

This plan is a living document. The risk areas discussed above will be resolved by FAA or Contractor action as the program progresses. Additional risk areas will be identified during the course of the program and will be added to this plan by the Risk Manager. In keeping this plan curr^nt, the Risk Manager will require each risk element to be addressed during meetings, briefings and reviews scheduled as project milestones, and when new risk areas are identified, they will be evaluated, and if significant enough, they will be added.

Table G-1 Quantification of Probability and Impact of Technical Failure

Hardware

TECHNICAL DRIVERS		MAGNITUDE: LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
REQUIREMENTS				
COMPLEXITY	.3	Simple or easily allocatable	Moderate, can be allocated	Significant or difficult to allocate
SIZE	.25	Small or easily broken down into work units	Medium, or can be broken down into work units	Large or cannot be broken down into work loads
STABILITY	.3	Little or no change to established baseline	Some change in baseline expected	Rapidly changing or no baseline
PDSS	0	Agreed to support concept	Roles and missions issues unresolved	No support concept or major unresolved issues
R&M	.45	Allocatable to hardware and software components	Requirements can be defined	Can only be addressed at the total system level
CONSTRAINTS				
COMPUTER RESOURCES	.2	Mature, growth capacity within design, flexible	Available, some growth capacity	New development no growth capacity, inflexible
PERSONNEL	0	Available, in place, experienced, stable	Available, but not in place, some experience	High turnover, little or no experience, not available
STANDARDS	.25	Appropriately tailored for application	Some tailoring, all not reviewed for applicability	No tailoring, none applied to the contract
GFE/GFP	.3	Meets requirements, available	May meet requirements, uncertain availability	Not compatible with system requirements, unavailable
ENVIRONMENT	.2	Little or no impact on design	Some impact on design	Major impact on design
TECHNOLOGY				
LANGUAGE	0	Mature, approved HOL used	Approved or Non-approved HOL	Significant use of assembly language
HARDWARE	.2	Mature, available	Some development or available	Total new development
TOOLS	.1	Documented, validated, in place	Available, validated some development	Unvalidated, proprietary, major development
DATA RIGHTS	0	Fully compatible with support and follow-on	Minor incompatibilities with support and follow-on	Incompatible with support and follow-on
EXPERIENCE	.15	Greater than 3 to 5 years	Less than 3 to 5 years	Little or none
DEVELOPMENTAL APPROACH				
PROTOTYPES & REUSE	.5	Used, documented sufficiently for use	Some use and documentation	No use and/or no documentation
DOCUMENTATION	.4	Correct and available	Some deficiencies, available	Nonexistent
ENVIRONMENT	0	In place, validated, experience with use	Minor modifications, tools available	Major development effort
MANAGEMENT APPROACH	.25	Existing product and process controls	Product & process controls need enhancement	Weak or nonexistent
INTEGRATION	.4	Internal and external controls in place	Internal or external controls not in place	Weak or nonexistent
IMPACT	.28	Minimal to small reduction in technical performance	Some reduction in technical performance	Significant degradation to nonachievement of technical performance

Table G-2 Quantification of Probability and Impact of Technical Failure

Hardware

OPERATIONAL DRIVERS		MAGNITUDE LOW (0.0 – 0.3)	MAGNITUDE MEDIUM (0.4 – 0.5)	MAGNITUDE HIGH (0.6 – 1.0)
USER PERSPECTIVE				
REQUIREMENTS	.4	Compatible with the user environment	Some incompatibilities	Major incompatibilities with "ops" concepts
STABILITY	.4	Little or no change	Some controlled change	Uncontrolled change
TEST ENVIRONMENT	.3	Representative of the user environment	Some aspects are not representative	Major disconnects with user environment
OT&E RESULTS	0	Test errors/failures are correctable	Some errors/failures are not correctable before IOC	Major corrections necessary
QUANTIFICATION	0	Primarily objective	Some subjectivity	Primarily subjective
TECHNICAL PERFORMANCE				
USABILITY	.3	User friendly	Mildly unfriendly	User unfriendly
RELIABILITY	.25	Predictable performance	Some aspects unpredictable	Unpredictable
FLEXIBILITY	.4	Adaptable with threat	Some aspects are not adaptable	Critical functions not adaptable
SUPPORTABILITY	.3	Timely incorporation	Response times inconsistent with need	Unresponsive
INTEGRITY	.3	Responsive to update	Hidden linkages, controlled access	Insecure
PERFORMANCE ENVELOPE				
ADEQUACY	.3	Full compatibility	Some limitations	Inadequate
EXPANDABILITY	.45	Easily expanded	Can be expanded	No expansion
ENHANCEMENTS	.4	Timely incorporation	Some lag	Major delays
THREAT	.4	Responsive to change	Cannot respond to some changes	Unresponsive
IMPACT	.36	Full mission capability	Some limitations on mission performance	Severe performance limitations

Table G-3 Quantification of Probability and Impact of Support Failure

Hardware

SUPPORT DRIVERS		MAGNITUDE LOW (0.0 - 0.3)	MAGNITUDE MEDIUM (0.4 - 0.5)	MAGNITUDE HIGH (0.6 - 1.0)
DESIGN				
COMPLEXITY	.25	Structurally maintainable	Certain aspects difficult	Extremely difficult to maintain
DOCUMENTATION	.3	Adequate	Some deficiencies	Inadequate
COMPLETENESS	0	Little additional for PDSS incorporation	Some PDSS incorporation	Extensive PDSS incorporation
CONFIGURATION MANAGEMENT	.4	Sufficient, in place	Some shortfalls	Insufficient
STABILITY	.4	Little or no change	Moderate, controlled change	Rapid or uncontrolled change
RESPONSIBILITIES				
MANAGEMENT	.4	Defined, assigned responsibilities	Some roles and mission issues	Undefined or unassigned
CONFIGURATION MANAGEMENT	.3	Single point control	Defined control points	Multiple control points
TECHNICAL MANAGEMENT	.3	Consistent with operational needs	Some inconsistencies	Major inconsistencies
CHANGE IMPLEMENTATION	.3	Responsive to user needs	Acceptable delays	Nonresponsive to user needs
TOOLS & MANAGEMENT				
FACILITIES	.3	In place, little change	In place, some modification	Nonexistent or extensive change
SOFTWARE TOOLS	0	Delivered, certified, sufficient	Some resolvable concerns	Not delivered, certified, or sufficient
COMPUTER HARDWARE	.4	Compatible with "ops" system	Minor incompatibilities	Major incompatibilities
PRODUCTION	.15	Sufficient for fielded units	Some capacity questions	Insufficient
DISTRIBUTION	.2	Controlled, responsive	Minor response concerns	Uncontrolled or nonresponsive
SUPPORTABILITY				
CHANGES	0	Within projections	Slight deviations	Major deviations
OPERATIONAL INTERFACES	.3	Defined, controlled	Some "hidden" linkages	Extensive linkages
PERSONNEL	.3	In place, sufficient, experience	Minor discipline mix concerns	Significant concerns
RELEASE CYCLE	.3	Responsive to user requirements	Minor incompatibilities	Nonresponsive to user needs
PROCEDURES	.3	In place, adequate	Some concerns	Nonexistent or inadequate
IMPACT	.31	Responsive software support	Minor delays in software modifications	Nonresponsive or unsupportable software

Table G-4 Quantification of Probability and Impact of Support Failure

Hardware

COST DRIVERS		MAGNITUDE: LOW (0.0 - 0.3)	MAGNITUDE: MEDIUM (0.4 - 0.5)	MAGNITUDE: HIGH (0.6 - 1.0)
REQUIREMENTS				
SIZE	.3	Small, non-complex, or easily decomposed	Medium, moderate complexity, decomposable	Large, highly complex, or not decomposable
RESOURCE CONSTRAINTS	.4	Little or no hardware imposed constraints	Some hardware imposed constraints	Significant hardware imposed constraints
APPLICATION	.5	Non real-time, little system interdependency	Embedded, some system interdependency	Real-time, embedded, strong interdependency
TECHNOLOGY	.3	Mature, existent, in-house experience	Existent, some in-house experience	New or new application, little experience
REQUIREMENTS STABILITY	.45	Little or no change to established baseline	Some change in baseline expected	Rapidly changing or no baseline
PERSONNEL				
AVAILABILITY	.3	In place, little turnover expected	Available, some turnover expected	High turnover, not available
MIX	.3	Good mix of software disciplines	Some disciplines inappropriately represented	Some disciplines not represented
EXPERIENCE	.3	High experience ratio	Average experience ratio	Low experience ratio
MANAGEMENT ENGINEERING	.3	Strong management approach	Good personnel management approach	Weak personnel management approach
REUSABLE SOFTWARE				
AVAILABILITY	0	Compatible with need dates	Delivery dates in question	Incompatible with need dates
MODIFICATIONS	0	Little or no change	Some change	Extensive changes
LANGUAGE	0	Compatible with system & PDSS requirements	Partial compatibility with requirements	Incompatible with system or PDSS requirements
RIGHTS	0	Compatible with PDSS & competition requirements	Partial compatibility with PDSS, some competition	Incompatible with PDSS concept, noncompetitive
CERTIFICATION	0	Verified performance, application compatible	Some application compatible PDSS, some competition	Unverified, little test data available
TOOLS AND ENVIRONMENT				
FACILITIES	.4	Little or no modifications	Some modifications, existent	Major modifications, nonexistent
AVAILABILITY	.3	In place, meets need dates	Some compatibility with need dates	Nonexistent, does not meet need dates
RIGHTS	0	Compatible with PDSS & development plans	Partial compatibility with PDSS & development plans	Incompatible with PDSS & development plans
CONFIGURATION MANAGEMENT	.4	Fully controlled	Some controls	No controls
IMPACT	.35	Sufficient financial resources	Some shortage of financial resources, possible overrun	Significant financial shortages, budget overrun likely

Table G-5 Quantification of Probability and Impact of Schedule Failure

Hardware

SCHEDULE DRIVERS		MAGNITUDE LOW (0.0 – 0.3)	MAGNITUDE MEDIUM (0.4 – 0.5)	MAGNITUDE HIGH (0.6 – 1.0)
RESOURCES				
PERSONNEL	.3	Good discipline mix in place	Some disciplines not available	Questionable mix and/or availability
FACILITIES	.3	Existent, little or no modification	Existent, some modification	Nonexistent, extensive changes
FINANCIAL	.4	Sufficient budget allocated	Some questionable allocations	Budget allocation in doubt
NEED DATES				
THREAT	.3	Verified Projections	Some unstable aspects	Rapidly changing
ECONOMIC	.4	Stable commitments	Some uncertain commitments	Unstable, fluctuating commitments
POLITICAL	1.0	Little projected sensitivity	Some limited sensitivity	Extreme sensitivity
GFE/GFP	.4	Available, certified	Certification or delivery questions	No application evidence
TOOLS	.4	In place, available	Some deliveries in question	Little or none
TECHNOLOGY				
AVAILABILITY	.25	In place	Baselined, some unknowns	Unknown, no baseline
MATURITY	.2	Application verified	Controllable change projected	Rapid or uncontrolled change
EXPERIENCE	.3	Extensive application	Some dependency on new technology	Incompatible with existing technology
REQUIREMENTS				
DEFINITION	.3	Known, baselined	Baselined, some unknowns	Unknown, no baseline
STABILITY	.2	Little or no change projected	Controllable change projected	Rapid or uncontrollable change
COMPLEXITY	.25	Compatible with existing technology	Some dependency on new technology	Incompatible with existing technology
IMPACT	.33	Realistic, achievable schedule	Possible slippage in IOC	Unachievable IOC

Table G-1 Quantification of Probability and Impact of Technical Failure

Software

TECHNICAL DRIVERS		LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
REQUIREMENTS				
COMPLEXITY	.4	Simple or easily allocatable	Moderate, can be allocated	Significant or difficult to allocate
SIZE	.3	Small or easily broken down into work units	Medium, or can be broken down into work units	Large or cannot be broken down into work loads
STABILITY	.4	Little or no change to established baseline	Some change in baseline expected	Rapidly changing or no baseline
PDSS	0	Agreed to support concept	Roles and missions issues unresolved	No support concept or major unresolved issues
R&M	.2	Allocatable to hardware and software components	Requirements can be defined	Can only be addressed at the total system level
CONSTRAINTS				
COMPUTER RESOURCES	.2	Mature, growth capacity within design, flexible	Available, some growth capacity	New development no growth capacity, inflexible
PERSONNEL	.4	Available, in place, experienced, stable	Available, but not in place, some experience	High turnover, little or no experience, not available
STANDARDS	.3	Appropriately tailored for application	Some tailoring, all not reviewed for applicability	No tailoring, none applied to the contract
GFE/GFP	.2	Meets requirements, available	May meet requirements, uncertain availability	Not compatible with system requirements, unavailable
ENVIRONMENT	.3	Little or no impact on design	Some impact on design	Major impact on design
TECHNOLOGY				
LANGUAGE	.3	Mature [illegible]roved HOL use[illegible]	Approved or Non-approved HOL	Significant use of assembly language
HARDWARE	0	Mature, available	Some development or available	Total new development
TOOLS	.5	Documented, validated, in place	Available, validated some development	Unvalidated, proprietary, major development
DATA RIGHTS	.2	Fully compatible with support and follow-on	Minor incompatibilities with support and follow-on	Incompatible with support and follow-on
EXPERIENCE	.3	Greater than 3 to 5 years	Less than 3 to 5 years	Little or none
DEVELOPMENTAL APPROACH				
PROTOTYPES & REUSE	.5	Used, documented sufficiently for use	Some use and documentation	No use and/or no documentation
DOCUMENTATION	.2	Correct and available	Some deficiencies, available	[illegible]istent
ENVIRONMENT	.3	In place, validated, experience with use	Minor modifications, tools available	Major development effort
MANAGEMENT APPROACH	.3	Existing product and process controls	Product & process controls need enhancement	Weak or nonexistent
INTEGRATION	.4	Internal and external controls in place	Internal or external controls not in place	Weak or nonexistent
IMPACT	.29	Minimal to small reduction in technical performance	Some reduction in technical performance	Significant degradation to nonachievement of technical performance

Table G-2 Quantification of Probability and Impact of Technical Failure

Software

OPERATIONAL DRIVERS		MAGNITUDE LOW (0.0 – 0.3)	MEDIUM (0.4 – 0.5)	HIGH (0.6 – 1.0)
USER PERSPECTIVE				
REQUIREMENTS	.4	Compatible with the user environment	Some incompatibilities	Major incompatibilities with "ops" concepts
STABILITY	.5	Little or no change	Some controlled change	Uncontrolled change
TEST ENVIRONMENT	.3	Representative of the user environment	Some aspects are not representative	Major disconnects with user environment
OT&E RE[illegible]TS	.3	Test errors/failures are correctable	Some errors/failures are not correctable before IOC	Major corrections necessary
QUANTIFICATION	.3	Primarily objective	Some subjectivity	Primarily subjective
TECHNICAL PERFORMANCE				
USABILITY	.2	User friendly	Mildly unfriendly	User unfriendly
RELIABILITY	.3	Predictable performance	Some aspects unpredictable	Unpredictable
FLEXIBILITY	.3	Adaptable with threat	Some aspects are not adaptable	Critical functions not adaptable
SUPPORTABILITY	.3	Timely incorporation	Response times inconsistent with need	Unresponsive
INTEGRITY	.7	Responsive to update	Hidden linkages, controlled access	Insecure
PERFORMANCE ENVELOPE				
ADEQUACY	.4	Full compatibility	Some limitations	Inadequate
EXPANDABILITY	.5	Easily expanded	Can be expanded	No expansion
ENHANCEMENTS	.4	Timely incorporation	Some lag	Major delays
THREAT	0	Responsive to change	Cannot respond to some changes	Unresponsive
IMPACT	.35	Full mission capability	Some limitations on mission performance	Severe performance limitations

Table G-3 Quantification of Probability and Impact of Support Failure

Software

SUPPORT DRIVERS		LOW (0.0 - 0.3)	MEDIUM (0.4 - 0.5)	HIGH (0.6 - 1.0)
DESIGN				
COMPLEXITY	.3	Structurally maintainable	Certain aspects difficult	Extremely difficult to maintain
DOCUMENTATION	.3	Adequate	Some deficiencies	Inadequate
COMPLETENESS	0	Little additional for PDSS incorporation	Some PDSS incorporation	Extensive PDSS incorporation
CONFIGURATION MANAGEMENT	.3	Sufficient, in place	Some shortfalls	Insufficient
STABILITY	.3	Little or no change	Moderate, controlled change	Rapid or uncontrolled change
RESPONSIBILITIES				
MANAGEMENT	.3	Defined, assigned responsibilities	Some roles and mission issues	Undefined or unassigned
CONFIGURATION MANAGEMENT	.3	Single point control	Defined control points	Multiple control points
TECHNICAL MANAGEMENT	.2	Consistent with operational needs	Some inconsistencies	Major inconsistencies
CHANGE IMPLEMENTATION	.3	Responsive to user needs	Acceptable delays	Nonresponsive to user needs
TOOLS & MANAGEMENT				
FACILITIES	.3	In place, little change	In place, some modification	Nonexistent or extensive change
SOFTWARE TOOLS	.5	Delivered, certified, sufficient	Some resolvable concerns	Not delivered, certified, or sufficient
COMPUTER HARDWARE	0	Compatible with "ops" system	Minor incompatibilities	Major incompatibilities
PRODUCTION	0	Sufficient for fielded units	Some capacity questions	Insufficient
DISTRIBUTION	0	Controlled, responsive	Minor response concerns	Uncontrolled or nonresponsive
SUPPORTABILITY				
CHANGES	.5	Within projections	Slight deviations	Major deviations
OPERATIONAL INTERFACES	.6	Defined, controlled	Some "hidden" linkages	Extensive linkages
PERSONNEL	.3	In place, sufficient, experience	Minor discipline mix concerns	Significant concerns
RELEASE CYCLE	0	Responsive to user requirements	Minor incompatibilities	Nonresponsive to user needs
PROCEDURES	.3	In place, adequate	Some concerns	Nonexistent or inadequate
IMPACT	.26	Responsive software support	Minor delays in software modifications	Nonresponsive or unsupportable software

Table G-4 Quantification of Probability and Impact of Support Failure

Software

COST DRIVERS		MAGNITUDE: LOW (0.0 – 0.3)	MAGNITUDE: MEDIUM (0.4 – 0.5)	MAGNITUDE: HIGH (0.6 – 1.0)
REQUIREMENTS				
SIZE	.5	Small, non-complex, or easily decomposed	Medium, moderate complexity, decomposable	Large, highly complex, or not decomposable
RESOURCE CONSTRAINTS	.3	Little or no hardware imposed constraints	Some hardware imposed constraints	Significant hardware imposed constraints
APPLICATION	.5	Non real-time, little system interdependency	Embedded, some system interdependency	Real-time, embedded, strong interdependency
TECHNOLOGY	.3	Mature, existent, in-house experience	Existent, some in-house experience	New or new application, little experience
REQUIREMENTS STABILITY	.4	Little or no change to established baseline	Some change in baseline expected	Rapidly changing or no baseline
PERSONNEL				
AVAILABILITY	.3	In place, little turnover expected	Available, some turnover expected	High turnover, not available
MIX	.3	Good mix of software disciplines	Some disciplines inappropriately represented	Some disciplines not represented
EXPERIENCE	.4	High experience ratio	Average experience ratio	Low experience ratio
MANAGEMENT ENGINEERING	.3	Strong management approach	Good personnel management approach	Weak personnel management approach
REUSABLE SOFTWARE				
AVAILABILITY	.4	Compatible with need dates	Delivery dates in question	Incompatible with need dates
MODIFICATIONS	.5	Little or no change	Some change	Extensive changes
LANGUAGE	.3	Compatible with system & PDSS requirements	Partial compatibility with requirements	Incompatible with system or PDSS requirements
RIGHTS	.5	Compatible with PDSS & competition requirements	Partial compatibility with PDSS, some competition	Incompatible with PDSS concept, noncompetitive
CERTIFICATION	0	Verified performance, application compatible	Some application compatible PDSS, some competition	Unverified, little test data available
TOOLS AND ENVIRONMENT				
FACILITIES	.4	Little or no modifications	Some modifications, existent	Major modifications, nonexistent
AVAILABILITY	.3	In place, meets need dates	Some compatibility with need dates	Nonexistent, does not meet need dates
RIGHTS	.4	Compatible with PDSS & development plans	Partial compatibility with PDSS & development plans	Incompatible with PDSS & development plans
CONFIGURATION MANAGEMENT	.3	Fully controlled	Some controls	No controls
IMPACT	.36	Sufficient financial resources	Some shortage of financial resources, possible overrun	Significant financial shortages, budget overrun likely

Table G-5 Quantification of Probability and Impact of Schedule Failure

Software

SCHEDULE DRIVERS		MAGNITUDE LOW (0.0 - 0.3)	MAGNITUDE MEDIUM (0.4 - 0.5)	MAGNITUDE HIGH (0.6 - 1.0)
RESOURCES				
PERSONNEL	.3	Good discipline mix in place	Some disciplines not available	Questionable mix and/or availability
FACILITIES	.5	Existent, little or no modification	Existent, some modification	Nonexistent, extensive changes
FINANCIAL	.4	Sufficient budget allocated	Some questionable allocations	Budget allocation in doubt
NEED DATES				
THREAT	0	Verified Projections	Some unstable aspects	Rapidly changing
ECONOMIC	.4	Stable commitments	Some uncertain commitments	Unstable, fluctuating commitments
POLITICAL	.5	Little projected sensitivity	Some limited sensitivity	Extreme sensitivity
GFE/GFP	.2	Available, certified	Certification or delivery questions	No application evidence
TOOLS	.4	In place, available	Some deliveries in question	Little or none
TECHNOLOGY				
AVAILABILITY	.3	In place	Baselined, some unknowns	Unknown, no baseline
MATURITY	.4	Application verified	Controllable change projected	Rapid or uncontrolled change
EXPERIENCE	.2	Extensive application	Some dependency on new technology	Incompatible with existing technology
REQUIREMENTS				
DEFINITION	.3	Known, baselined	Baselined, some unknowns	Unknown, no baseline
STABILITY	.4	Little or no change projected	Controllable change projected	Rapid or uncontrollable change
COMPLEXITY	.3	[illegible] with [illegible] technology	Some dependency on new technology	Incompatible with existing technology
IMPACT	.34	Realistic, achievable schedule	Possible slippage in IOC	Unachievable IOC

Table G-1 Quantification of Probability and Impact of Technical Failure

NAS/Other Systems Integration

TECHNICAL DRIVERS		MAGNITUDE: LOW (0.0 - 0.3)	MAGNITUDE: MEDIUM (0.4 - 0.5)	MAGNITUDE: HIGH (0.6 - 1.0)
REQUIREMENTS				
COMPLEXITY	.35	Simple or easily allocatable	Moderate, can be allocated	Significant or difficult to allocate
SIZE	.28	Small or easily broken down into work units	Medium, or can be broken down into work units	Large or cannot be broken down into work loads
STABILITY	.35	Little or no change to established baseline	Some change in baseline expected	Rapidly changing or no baseline
PDSS	0	Agreed to support concept	Roles and missions issues unresolved	No support concept or major unresolved issues
R&M	.3	Allocatable to hardware and software components	Requirements can be defined	Can only be addressed at the total system level
CONSTRAINTS				
COMPUTER RESOURCES	.2	Mature, growth capacity within design, flexible	Available, some growth capacity	New development no growth capacity, inflexible
PERSONNEL	.4	Available, in place, experienced, stable	Available, but not in place, some experience	High turnover, little or no experience, not available
STANDARDS	.28	Appropriately tailored for application	Some tailoring, all not reviewed for applicability	No tailoring, none applied to the contract
GFE/GFP	.25	Meets requirements, available	May meet requirements, uncertain availability	Not compatible with system requirements, unavailable
ENVIRONMENT	.25	Little or no impact on design	Some impact on design	Major impact on design
TECHNOLOGY				
LANGUAGE	.3	Mature, approved HOL used	Approved or Non-approved HOL	Significant use of assembly language
HARDWARE	.2	Mature, available	Some development or available	Total new development
TOOLS	.3	Documented, validated, in place	Available, validated some development	Unvalidated, proprietary, major development
DATA RIGHTS	.2	Fully compatible with support and follow-on	Minor incompatibilities with support and follow-on	Incompatible with support and follow-on
EXPERIENCE	.23	Greater than 3 to 5 years	Less than 3 to 5 years	Little or none
DEVELOPMENTAL APPROACH				
PROTOTYPES & REUSE	.5	Used, documented sufficiently for use	Some use and documentation	No use and/or no documentation
DOCUMENTATION	.3	Correct and available	Some deficiencies, available	Nonexistent
ENVIRONMENT	.3	In place, validated, experience with use	Minor modifications, tools available	Major development effort
MANAGEMENT APPROACH	.28	Existing product and process controls	Product & process controls need enhancement	Weak or nonexistent
INTEGRATION	.4	Internal and external controls in place	Internal or external controls not in place	Weak or nonexistent
IMPACT	.30	Minimal to small reduction in technical performance	Some reduction in technical performance	Significant degradation to nonachievement of technical performance

Table G-2 Quantification of Probability and Impact of Technical Failure

NAS/Other Systems Integration

OPERATIONAL DRIVERS		MAGNITUDE: LOW (0.0 – 0.3)	MEDIUM (0.4 – 0.5)	HIGH (0.6 – 1.0)
USER PERSPECTIVE				
REQUIREMENTS	.4	Compatible with the user environment	Some incompatibilities	Major incompatibilities with "ops" concepts
STABILITY	.45	Little or no change	Some controlled change	Uncontrolled change
TEST ENVIRONMENT	.3	Representative of the user environment	Some aspects are not representative	Major disconnects with user environment
OT&E RESULTS	.3	Test errors/failures are correctable	Some errors/failures are not correctable before IOC	Major corrections necessary
QUANTIFICATION	.3	Primarily objective	Some subjectivity	Primarily subjective
TECHNICAL PERFORMANCE				
USABILITY	.25	User friendly	Mildly unfriendly	User unfriendly
RELIABILITY	.28	Predictable performance	Some aspects unpredictable	Unpredictable
FLEXIBILITY	.35	Adaptable with threat	Some aspects are not adaptable	Critical functions not adaptable
SUPPORTABILITY	.3	Timely incorporation	Response times inconsistent with need	Unresponsive
INTEGRITY	.5	Responsive to update	Hidden linkages, controlled access	Insecure
PERFORMANCE ENVELOPE				
ADEQUACY	.35	Full compatibility	Some limitations	Inadequate
EXPANDABILITY	.48	Easily expanded	Can be expanded	No expansion
ENHANCEMENTS	.4	Timely incorporation	Some lag	Major delays
THREAT	.4	Responsive to change	Cannot respond to some changes	Unresponsive
IMPACT	.37	Full mission capability	Some limitations on mission performance	Severe performance limitations

Table G-3 Quantification of Probability and Impact of Support Failure

NAS/Other Systems Integration

SUPPORT DRIVERS		MAGNITUDE LOW (0.0 – 0.3)	MEDIUM (0.4 – 0.5)	HIGH (0.6 – 1.0)
DESIGN				
COMPLEXITY	.28	Structurally maintainable	Certain aspects difficult	Extremely difficult to maintain
DOCUMENTATION	.3	Adequate	Some deficiencies	Inadequate
COMPLETENESS	0	Little additional for PDSS incorporation	Some PDSS incorporation	Extensive PDSS incorporation
CONFIGURATION MANAGEMENT	.35	Sufficient, in place	Some shortfalls	Insufficient
STABILITY	.35	Little or no change	Moderate, controlled change	Rapid or uncontrolled change
RESPONSIBILITIES				
MANAGEMENT	.35	Defined assigned responsibilities	Some roles and mission issues	Undefined or unassigned
CONFIGURATION MANAGEMENT	.3	Single point control	Defined control points	Multiple control points
TECHNICAL MANAGEMENT	.25	Consistent with operational needs	Some inconsistencies	Major inconsistencies
CHANGE IMPLEMENTATION	.3	Responsive to user needs	Acceptable delays	Nonresponsive to user needs
TOOLS & MANAGEMENT				
FACILITIES	.3	In place, little change	In place, some modification	Nonexistent or extensive change
SOFTWARE TOOLS	.5	Delivered, certified, sufficient	Some resolvable concerns	Not delivered, certified, or sufficient
COMPUTER HARDWARE	.4	Compatible with "ops" system	Minor incompatibilities	Major incompatibilities
PRODUCTION	.15	Sufficient for fielded units	Some capacity questions	Insufficient
DISTRIBUTION	.2	Controlled, responsive	Minor response concerns	Uncontrolled or nonresponsive
SUPPORTABILITY				
CHANGES	.4	Within projections	Slight deviations	Major deviations
OPERATIONAL INTERFACES	.45	Defined, controlled	Some "hidden" linkages	Extensive linkages
PERSONNEL	.3	In place, sufficient, experience	Minor discipline mix concerns	Significant concerns
RELEASE CYCLE	.3	Responsive to user requirements	Minor incompatibilities	Nonresponsive to user needs
PROCEDURES	.3	In place, adequate	Some concerns	Nonexistent or inadequate
IMPACT	.32	Responsive software support	Minor delays in software modifications	Nonresponsive or unsupportable software

Table G–4 Quantification of Probability and Impact of Support Failure

NAS/Other Systems Integration

COST DRIVERS		MAGNITUDE LOW (0.0 – 0.3)	MEDIUM (0.4 – 0.5)	HIGH (0.6 – 1.0)
REQUIREMENTS				
SIZE	.4	Small, non-complex, or easily decomposed	Medium, moderate complexity, decomposable	Large, highly complex, or not decomposable
RESOURCE CONSTRAINTS	.35	Little or no hardware imposed constraints	Some hardware imposed constraints	Significant hardware imposed constraints
APPLICATION	.5	Non real-time, little system interdependency	Embedded, some system interdependency	Real-time, embedded, strong interdependency
TECHNOLOGY	.3	Mature, existent, in-house experience	Existent, some in-house experience	New or new application, little experience
REQUIREMENTS STABILITY	.43	Little or no change to established baseline	Some change in baseline expected	Rapidly changing or no baseline
PERSONNEL				
AVAILABILITY	.3	In place, little turnover expected	Available, some turnover expected	High turnover, not available
MIX	.3	Good mix of software disciplines	Some disciplines inappropriately represented	Some disciplines not represented
EXPERIENCE	.35	High experience ratio	Average experience ratio	Low experience ratio
MANAGEMENT ENGINEERING	.3	Strong management approach	Good personnel management approach	Weak personnel management approach
REUSABLE SOFTWARE				
AVAILABILITY	.4	Compatible with need dates	Delivery dates in question	Incompatible with need dates
MODIFICATIONS	.5	Little or no change	Some change	Extensive changes
LANGUAGE	.3	Compatible with system & PDSS requirements	Partial compatibility with requirements	Incompatible with system or PDSS requirements
RIGHTS	.5	Compatible with PDSS & competition requirements	Partial compatibility with PDSS, some competition	Incompatible with PDSS concept, noncompetitive
CERTIFICATION	0	Verified performance, application compatible	Some application compatible PDSS, some competition	Unverified, little test data available
TOOLS AND ENVIRONMENT				
FACILITIES	.4	Little or no modifications	Some modifications, existent	Major modifications, nonexistent
AVAILABILITY	.3	In place, meets need dates	Some compatibility with need dates	Nonexistent, does not meet need dates
RIGHTS	.4	Compatible with PDSS & development plans	Partial compatibility with PDSS & development plans	Incompatible with PDSS & development plans
CONFIGURATION MANAGEMENT	.35	Fully controlled	Some controls	No controls
IMPACT	.38	Sufficient financial resources	Some shortage of financial resources, possible overrun	Significant financial shortages, budget overrun likely

Table G-5 Quantification of Probability and Impact of Schedule Failure

NAS/Other Systems Integration

SCHEDULE DRIVERS		MAGNITUDE: LOW (0.0 - 0.3)	MAGNITUDE: MEDIUM (0.4 - 0.5)	MAGNITUDE: HIGH (0.6 - 1.0)
RESOURCES				
PERSONNEL	.3	Good discipline mix in place	Some disciplines not available	Questionable mix and/or availability
FACILITIES	.4	Existent, little or no modification	Existent, some modification	Nonexistent, extensive changes
FINANCIAL	.4	Sufficient budget allocated	Some questionable allocations	Budget allocation in doubt
NEED DATES				
THREAT	.3	Verified Projections	Some unstable aspects	Rapidly changing
ECONOMIC	.4	Stable commitments	Some uncertain commitments	Unstable, fluctuating commitments
POLITICAL	1.0	Little projected sensitivity	Some limited sensitivity	Extreme sensitivity
GFE/GFP	.3	Available, certified	Certification or delivery questions	No application evidence
TOOLS	.4	In place, available	Some deliveries in question	Little or none
TECHNOLOGY				
AVAILABILITY	.28	In place	Baselined, some unknowns	Unknown, no baseline
MATURITY	.3	Application verified	Controllable change projected	Rapid or uncontrolled change
EXPERIENCE	.25	Extensive application	Some dependency on new technology	Incompatible with existing technology
REQUIREMENTS				
DEFINITION	.3	Known, baselined	Baselined, some unknowns	Unknown, no baseline
STABILITY	.3	Little or no change projected	Controllable change projected	Rapid or uncontrollable change
COMPLEXITY	.28	Compatible with existing technology	Some dependency on new technology	Incompatible with existing technology
IMPACT	.36	Realistic, achievable schedule	Possible slippage in IOC	Unachievable IOC

APPENDIX T

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OFFICE OF MANAGEMENT AND BUDGET
WASHINGTON, D.C. 20503

April 5, 1976

CIRCULAR NO. A-109

TO THE HEADS OF EXECUTIVE DEPARTMENTS AND ESTABLISHMENTS

SUBJECT: Major System Acquisitions

1. Purpose. This Circular establishes policies, to be followed by executive branch agencies in the acquisition of major systems.

2. Background. The acquisition of major systems by the Federal Government constitutes one of the most crucial and expensive activities performed to meet national needs. Its impact is critical on technology, on the Nation's economic and fiscal policies, and on the accomplishment of Government agency missions in such fields as defense, space, energy and transportation. For a number of years, there has been deep concern over the effectiveness of the management of major system acquisitions. The report of the Commission on Government Procurement recommended basic changes to improve the process of acquiring major systems. This Circular is based on executive branch consideration of the Commission's recommendations.

3. Responsibility. Each agency head has the responsibility to ensure that the provisions of this Circular are followed. This Circular provides administrative direction to heads of agencies and does not establish and shall not be construed to create any substantive or procedural basis for any person to challenge any agency action or inaction on the basis that such action was not in accordance with this Circular.

4. Coverage. This Circular covers and applies to:

a. Management of the acquisition of major systems, including: • Analysis of agency missions • Determination of mission needs • Setting of program objectives • Determination of system requirements • System program planning • Budgeting • Funding • Research • Engineering • Development • Testing and evaluation • Contracting • Production • Program and management control • Introduction

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of the system into use or otherwise successful achievement of program objectives.

b. All programs for the acquisition of major systems even though:

(1) The system is one-of-a-kind.

(2) The agency's involvement in the system is limited to the development of demonstration hardware for optional use by the private sector rather than for the agency's own use.

5. Definitions. As used in this Circular:

a. Executive agency (hereinafter referred to as agency) means an executive department, and an independent establishment within the meaning of sections 101 and 104(1), respectively, of Title 5, United States Code.

b. Agency component means a major organizational subdivision of an agency. For example: The Army, Navy, Air Force, and Defense Supply Agency are agency components of the Department of Defense. The Federal Aviation Administration, Urban Mass Transportation Administration, and the Federal Highway Administration are agency components of the Department of Transportation.

c. Agency missions means those responsibilities for meeting national needs assigned to a specific agency.

d. Mission need means a required capability within an agency's overall purpose, including cost and schedule considerations.

e. Program objectives means the capability, cost and schedule goals being sought by the system acquisition program in response to a mission need.

f. Program means an organized set of activities directed toward a common purpose, objective, or goal undertaken or proposed by an agency in order to carry out responsibilities assigned to it.

g. System design concept means an idea expressed in terms of general performance, capabilities, and characteristics of hardware and software oriented either to operate or to be operated as an integrated whole in meeting a mission need.

h. Major system means that combination of elements that will function together to produce the capabilities required to fulfill a mission need. The elements may include, for example, hardware, equipment, software, construction, or other improvements or real property. Major system acquisition programs are those programs that (1) are directed at and critical to fulfilling an agency mission, (2) entail the allocation of relatively large resources, and (3) warrant special management attention. Additional criteria and relative dollar thresholds for the determination of agency programs to be considered major systems under the purview of this Circular, may be established at the discretion of the agency head.

i. System acquisition process means the sequence of acquisition activities starting from the agency's reconciliation of its mission needs, with its capabilities, priorities and resources, and extending through the introduction of a system into operational use or the otherwise successful achievement of program objectives.

j. Life cycle cost means the sum total of the direct, indirect, recurring, nonrecurring, and other related costs incurred, or estimated to be incurred, in the design, development, production, operation, maintenance and support of a major system over its anticipated useful life span.

6. General policy. The policies of this Circular are designed to assure the effectiveness and efficiency of the process of acquiring major systems. They are based on the general policy that Federal agencies, when acquiring major systems, will:

a. Express needs and program objectives in mission terms and not equipment terms to encourage innovation and competition in creating, exploring, and developing alternative system design concepts.

b. Place emphasis on the initial activities of the system acquisition process to allow competitive exploration of alternative system design concepts in response to mission needs.

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c. Communicate with Congress early in the system acquisition process by relating major system acquisition programs to agency mission needs. This communication should follow the requirements of Office of Management and Budget (OMB) Circular No. A-10 concerning information related to budget estimates and related materials.

d. Establish clear lines of authority, responsibility, and accountability for management of major system acquisition programs. Utilize appropriate managerial levels in decisionmaking, and obtain agency head approval at key decision points in the evolution of each acquisition program.

e. Designate a focal point responsible for integrating and unifying the system acquisition management process and monitoring policy implementation.

f. Rely on private industry in accordance with the policy established by OMB Circular No. A-76.

7. Major system acquisition management objectives. Each agency acquiring major systems should:

a. Ensure that each major system: Fulfills a mission need. Operates effectively in its intended environment. Demonstrates a level of performance and reliability that justifies the allocation of the Nation's limited resources for its acquisition and ownership.

b. Depend on, whenever economically beneficial, competition between similar or differing system design concepts throughout the entire acquisition process.

c. Ensure appropriate trade-off among investment costs, ownership costs, schedules, and performance characteristics.

d. Provide strong checks and balances by ensuring adequate system test and evaluation. Conduct such tests and evaluation independent, where practicable, of developer and user.

e. Accomplish system acquisition planning, built on analysis of agency missions, which implies appropriate resource allocation resulting from clear articulation of agency mission needs.

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f. Tailor an acquisition strategy for each program, as soon as the agency decides to solicit alternative system design concepts, that could lead to the acquisition of a new major system and refine the strategy as the program proceeds through the acquisition process. Encompass test and evaluation criteria and business management considerations in the strategy. The strategy could typically include: • Use of the contracting process as an important tool in the acquisition program • Scheduling of essential elements of the acquisition process • Demonstration, test, and evaluation criteria • Content of solicitations for proposals • Decisions on whom to solicit • Methods for obtaining and sustaining competition • Guidelines for the evaluation and acceptance or rejection of proposals • Goals for design-to-cost • Methods for projecting life cycle costs • Use of data rights • Use of warranties • Methods for analyzing and evaluating contractor and Government risks • Need for developing contractor incentives • Selection of the type of contract best suited for each stage in the acquisition process • Administration of contracts.

g. Maintain a capability to: • Predict, review, assess, negotiate and monitor costs for system development, engineering, design, demonstration, test, production, operation and support (i.e., life cycle costs) • Assess acquisition cost, schedule and performance experience against predictions, and provide such assessments for consideration by the agency head at key decision points • Make new assessments where significant costs, schedule or performance variances occur • Estimate life cycle costs during system design concept evaluation and selection, full-scale development, facility conversion, and production, to ensure appropriate trade-offs among investment costs, ownership costs, schedules, and performance • Use independent cost estimates, where feasible, for comparison purposes.

8. <u>Management structure</u>.

a. The head of each agency that acquires major systems will designate an acquisition executive to integrate and unify the management process for the agency's major system acquisitions and to monitor implementation of the policies and practices set forth in this Circular.

b. Each agency that acquires--or is responsible for activities leading to the acquisition of--major systems will establish clear lines of authority, responsibility, and accountability for management of its major system acquisition programs.

c. Each agency should preclude management layering and placing nonessential reporting procedures and paperwork requirements on program managers and contractors.

d. A program manager will be designated for each of the agency's major system acquisition programs. This designation should be made when a decision is made to fulfill a mission need by pursuing alternative system design concepts. It is essential that the program manager have an understanding of user needs and constraints, familiarity with development principles, and requisite management skills and experience. Ideally, management skills and experience would include: • Research and development • Operations • Engineering • Construction • Testing • Contracting • Prototyping and fabrication of complex systems • Production • Business • Budgeting • Finance. With satisfactory performance, the tenure of the program manager should be long enough to provide continuity and personal accountability.

e. Upon designation, the program manager should be given budget guidance and a written charter of his authority, responsibility, and accountability for accomplishing approved program objectives.

f. Agency technical management and Government laboratories should be considered for participation in agency mission analysis, evaluation of alternative system design concepts, and support of all development, test, and evaluation efforts.

g. Agencies are encouraged to work with each other to foster technology transfer, prevent unwarranted duplication of technological efforts, reduce system costs, promote standardization, and help create and maintain a competitive environment for an acquisition.

9. Key decisions. Technical and program decisions normally will be made at the level of the agency component or operating activity. However, the following four key decision points should be retained and made by the agency head:

a. Identification and definition of a specific mission need to be fulfilled, the relative priority assigned within the agency, and the general magnitude of resources that may be invested.

b. Selection of competitive system design concepts to be advanced to a test/demonstration phase or authorization to proceed with the development of a noncompetitive (single concept) system.

c. Commitment of a system to full-scale development and limited production.

d. Commitment of a system to full production.

10. Determination of mission needs.

a. Determination of mission need should be based on an analysis of an agency's mission reconciled with overall capabilities, priorities and resources. When analysis of an agency's mission shows that a need for a new major system exists, such a need should not be defined in equipment terms, but should be defined in terms of the mission, purpose, capability, agency components involved, schedule and cost objectives, and operating constraints. A mission need may result from a deficiency in existing agency capabilities or the decision to establish new capabilities in response to a technologically feasible opportunity. Mission needs are independent of any particular system or technological solution.

b. Where an agency has more than one component involved, the agency will assign the roles and responsibilities of each component at the time of the first key decision. The agency may permit two or more agency components to sponsor competitive system design concepts in order to foster innovation and competition.

c. Agencies should, as required to satisfy mission responsibilities, contribute to the technology base, effectively utilizing both the private sector and Government laboratories and in-house technical centers, by conducting, supporting, or sponsoring: • Research • System design concept studies • Proof of concept work • Exploratory subsystem development • Tests and evaluations. Applied technology efforts oriented to system developments should be performed in response to approved mission needs.

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11. <u>Alternative systems</u>.

a. Alternative system design concepts will be explored within the context of the agency's mission need and program objectives--with emphasis on generating innovation and conceptual competition from industry. Benefits to be derived should be optimized by competitive exploration of alternative system design concepts, and trade-offs of capability, schedule, and cost. Care should be exercised during the initial steps of the acquisition process not to conform mission needs or program objectives to any known systems or products that might foreclose consideration of alternatives.

b. Alternative system design concepts will be solicited from a broad base of qualified firms. In order to achieve the most preferred system solution, emphasis will be placed on innovation and competition. To this end, participation of smaller and newer businesses should be encouraged. Concepts will be primarily solicited from private industry; and when beneficial to the Government, foreign technology, and equipment may be considered.

c. Federal laboratories, federally funded research and development centers, educational institutions, and other not-for-profit organizations may also be considered as sources for competitive system design concepts. Ideas, concepts, or technology, developed by Government laboratories or at Government expense, may be made available to private industry through the procurement process or through other established procedures. Industry proposals may be made on the basis of these ideas, concepts, and technology or on the basis of feasible alternatives which the proposer considers superior.

d. Research and development efforts should emphasize early competitive exploration of alternatives, as relatively inexpensive insurance against premature or preordained choice of a system that may prove to be either more costly or less effective.

e. Requests for alternative system design concept proposals will explain the mission need, schedule, cost, capability objectives, and operating constraints. Each offeror will be free to propose his own technical approach, main design features, subsystems, and alternatives to schedule, cost, and capability goals. In the conceptual and

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less than full-scale development stages, contractors should not be restricted by detailed Government specifications and standards.

f. Selections from competing system design concept proposals will be based on a review by a team of experts, preferably from inside and outside the responsible component development organization. Such a review will consider: (1) Proposed system functional and performance capabilities to meet mission needs and program objectives, including resources required and benefits to be derived by trade-offs, where feasible, among technical performance, acquisition costs, ownership costs, time to develop and procure; and (2) The relevant accomplishment record of competitors.

g. During the uncertain period of identifying and exploring alternative system design concepts, contracts covering relatively short time periods at planned dollar levels will be used. Timely technical reviews of alternative system design concepts will be made to effect the orderly elimination of those least attractive.

h. Contractors should be provided with operational test conditions, mission performance criteria, and life cycle cost factors that will be used by the agency in the evaluation and selection of the system(s) for full-scale development and production.

i. The participating contractors should be provided with relevant operational and support experience through the program manager, as necessary, in developing performance and other requirements for each alternative system design concept as tests and trade-offs are made.

j. Development of subsystems that are intended to be included in a major system acquisition program will be restricted to less than fully designed hardware (full-scale development) until the subsystem is identified as a part of a system candidate for full-scale development. Exceptions may be authorized by the agency head if the subsystems are long lead time items that fulfill a recognized generic need or if they have a high potential for common use among several existing or future systems.

12. Demonstrations.

a. Advancement to a competitive test/demonstration phase may be approved when the agency's mission need and program objectives are reaffirmed and when alternative system design concepts are selected.

b. Major system acquisition programs will be structured and resources planned to demonstrate and evaluate competing alternative system design concepts that have been selected. Exceptions may be authorized by the agency head if demonstration is not feasible.

c. Development of a single system design concept that has not been competitively selected should be considered only if justified by factors such as urgency of need, or by the physical and financial impracticality of demonstrating alternatives. Proceeding with the development of a noncompetitive (single concept) system may be authorized by the agency head. Strong agency program management and technical direction should be used for systems that have been neither competitively selected nor demonstrated.

13. Full-scale development and production.

a. Full-scale development, including limited production, may be approved when the agency's mission need and program objectives are reaffirmed and competitive demonstration results verify that the chosen system design concept(s) is sound.

b. Full production may be approved when the agency's mission need and program objectives are reaffirmed and when system performance has been satisfactorily tested, independent of the agency development and user organizations, and evaluated in an environment that assures demonstration in expected operational conditions. Exceptions to independent testing may be authorized by the agency head under such circumstances as physical or financial impracticability or extreme urgency. z

c. Selection of a system(s) and contractor(s) for full-scale development and production is to be made on the basis of (1) system performance measured against current mission need and program objectives, (2) an evaluation of estimated acquisition and ownership costs, and (3) such factors as

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contractor(s) demonstrated management, financial, and technical capabilities to meet program objectives.

d. The program manager will monitor system tests and contractor progress in fulfilling system performance, cost, and schedule commitments. Significant actual or forecast variances will be brought to the attention of the appropriate management authority for corrective action.

14. Budgeting and financing. Beginning with FY 1979 all agencies will, as part of the budget process, present budgets in terms of agency missions in consonance with Section 201(i) of the Budget and Accounting Act, 1921, as added by Section 601 of the Congressional Budget Act of 1974, and in accordance with OMB Circular A-11. In so doing, the agencies are desired to separately identify research and development funding for: (1) The general technology base in support of the agency's overall missions, (2) The specific development efforts in support of alternative system design concepts to accomplish each mission need, and (3) Full-scale developments. Each agency should ensure that research and development is not undesirably duplicated across its missions.

15. Information to Congress.

a. Procedures for this purpose will be developed in conjunction with the Office of Management and Budget and the various committees of Congress having oversight responsibility for agency activities. Beginning with FY 1979 budget each agency will inform Congress in the normal budget process about agency missions, capabilities, deficiencies, and needs and objectives related to acquisition programs, in consonance with Section 601(i) of the Congressional Budget Act of 1974.

b. Disclosure of the basis for an agency decision to proceed with a single system design concept without competitive selection and demonstration will be made to the congressional authorization and appropriation committees.

16. Implementation. All agencies will work closely with the Office of Management and Budget in resolving all implementation problems.

17. Submissions to Office of Management and Budget. Agencies will submit the following to OMB:

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a. Policy directives, regulations, and guidelines as they are issued.

b. Within six months after the date of this Circular, a time-phased action plan for meeting the requirements of this Circular.

c. Periodically, the agency approved exceptions permitted under the provisions of this Circular.

This information will be used by the OMB, in identifying major system acquisition trends and in monitoring implementations of this policy.

18. Inquiries. All questions or inquiries should be submitted to the OMB, Administrator for Federal Procurement Policy. Telephone number, area code, 202-395-4677.

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